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DEMONSTRATION OF SELECTIVE CATALYTIC REDUCTION (SCR) TECHNOLOGY FOR THE CONTROL OF NITROGEN OXIDE (NO_x) EMISSIONS FROM HIGH-SULFUR COAL-FIRED BOILERS

Plant Crist

Environmental Monitoring Program

Final Report

DOE DE-FC22-90PC89652
SCS C-91-000026

Prepared for:

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Cleared by DOE Patent Counsel on July 17, 1996.

DISCLAIMER

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Executive Summary

This report contains a summary and discussion of the results of Environmental Monitoring Program (EMP) activities conducted during the Clean Coal Technology (CCT) project entitled "Demonstration of Selective Catalytic Reduction (SCR) Technology for the Control of Nitrogen Oxide (NO_x) Emissions from High-Sulfur Coal-Fired Boilers." This project was conducted using flue gas from Unit 5 at Gulf Power Company's Plant Crist, located near Pensacola, Florida.

The primary goal of this project was to demonstrate the use of SCR to reduce NO_x emissions from pulverized-coal utility boilers using high-sulfur U.S. coal. The SCR test facility, built in and around the ductwork of Plant Crist Unit 5, consisted of three large SCR reactor units (Reactors A, B, and C), each with a design capacity of 5,000 standard cubic feet per minute (scfm) of flue gas, and six smaller reactors (Reactors D through J), each with a design capacity of 400 scfm of flue gas. The three large reactors contained commercially available SCR catalysts as offered by SCR catalyst suppliers. These reactors were coupled with small-scale air preheaters to evaluate (1) the long-term effects of SCR reaction chemistry on air preheater deposit formation and (2) the impact of these deposits on the performance of air preheaters. The small reactors were used to test additional varieties of commercially available catalysts.

The demonstration project was organized into three phases: (1) Phase I—Permitting, Environmental Monitoring Plan Preparation and Preliminary Engineering; (2) Phase II—Detail Design Engineering and Construction; and (3) Phase III—Operation, Testing, Disposition, and Final Report Preparation. All EMP monitoring was conducted during Phase III and included supplemental sampling and analysis of the Unit 5 feed coal and a number of SCR reactor inlet and outlet streams, together with compliance monitoring of the ash pond discharge. The Testing Phase consisted of four tasks, as follows:

- Task 1 (commissioning without catalysts and without ammonia injection) involved calibration of the venturi flow controllers upstream of each reactor; measurement of particle mass concentrations at the inlet and outlet of the Unit 5 hot-side electrostatic precipitator (ESP) at high and low load conditions; measurement of the particle mass loadings in the economizer bypass at low-load conditions and verification of the similarity of the particulate loadings, size distributions, and composition of the fly ash collected inside the eight high-dust reactors; measurement of baseline gas-phase flue gas composition; and determination of the degree of conversion of SO_2 to SO_3 across one large and one small reactor.

- Task 2 (commissioning without catalysts and with ammonia injection) was conducted to verify ammonia flow control, establish an ammonia mass balance, and measure ammonia loss in the absence of catalyst. Ammonia loss was measured on one large reactor and one small reactor.

- Task 3A (commissioning with catalysts and without ammonia injection) was combined with Task 3B (preliminary parametric tests). Tests were conducted to examine the conversion of SO_2 to SO_3 across the SCR reactors with catalysts installed and to evaluate the initial performance of the reactors with catalysts installed and with ammonia injection. Although the SO_2 conversion tests had originally been planned without ammonia injection, the tests were actually conducted with ammonia injection.

- Task 4 (long-term parametric tests) was intended to evaluate the long-term performance of the SCR reactors with catalysts installed and with ammonia injection. The parametric tests in this task included four additional series of tests in which measurements were made of a number of gas-phase constituents at various combinations of flue gas flow rate, temperature, and NH_3/NO_x ratio. When not undergoing parametric tests, each reactor was returned to its baseline operating condition for long-term performance evaluation.

In response to procedures developed by the Department of Energy to comply with the National Environmental Policy Act (NEPA) requirements, Southern Company Services was required to develop and implement an Environmental Monitoring Plan (EMP) for the Selective Catalytic Reduction Demonstration Project at Plant Crist (1). The EMP was developed to fulfill the following specific objectives:

- To provide monitoring data to fulfill project-related environmental compliance requirements of local, state, and federal regulatory agencies;

- To define and describe supplemental monitoring activities;

- To ensure that emissions and environmental impacts were consistent with projections provided in NEPA documents; and

- To develop an environmental record that can be used for future replication of the subject technology.

The following paragraphs summarize the results obtained from the EMP monitoring conducted during the SCR demonstration project. Detailed results of the project testing may be found in the Final Project Report (2).

- Apparent NO_x reduction efficiencies measured during the parametric tests showed that all of the SCR catalysts were capable of reductions from about 50 to nearly 100%, depending on reactor operating conditions. The mean reduction and observed range for each reactor, based on the parametric test data, are summarized below:

Reactor	Apparent NO_x Reduction Efficiencies, %		NH_3 Slip, ppmv
	Mean	Range	Range
A	79.9	61.8 - 94.1	0.8 - 29
B	84.5	66.9 - 99.8	<0.7 - 35.3
C	88.9	69.5 - 99.2	0.8 - 58
D	89.1	80.9 - 96.7	<1.3 - 94.1
E	81.7	62.0 - 93.9	< 0.1 - 68
F	84.7	70.6 - 96.0	<0.8 - 90.1
G	78.2	64.3 - 88.8	<0.7 - 94.1
J	68.7	51.2 - 85.7	<0.8 - 24.4

These reduction efficiencies should not be construed as necessarily reflecting the relative performance of the different catalysts in the reactors. Many factors impact the NO_x reduction efficiencies, and all of the reactors may not have experienced the same sequence of test parameters. In many cases, very high reductions efficiencies were achieved at conditions that may not be practical in routine operation. For example, at very high NO_x reduction efficiencies, ammonia slip could be as high as 90 ppmv. The ranges of ammonia slip measured during the parametric test sequences are also included in the table.

- In general, changes to the major SCR reactor operating parameters had the following impacts:

  — Increasing the NH_3/NO_x ratio resulted in greater NO_x reduction efficiency and increased ammonia slip.

  — Increasing SCR reactor residence time (i.e., reducing the flue gas flow rate) resulted in greater NO_x reduction efficiency and reduced ammonia slip.

  — Increasing reactor temperature did not have a definitive impact on NO_x reduction efficiency, but ammonia slip was reduced.

- The SO_3 concentration in the flue gas generally increased across the SCR reactors, due to the conversion of a portion of the SO_2. The fraction of SO_2 converted to SO_3 tended to increase with increasing reactor temperature and residence time. In many cases there was a slight decrease in SO_2 conversion as catalyst exposure time increased. Less than 0.5% of the SO_2 was converted to SO_3 in the majority of cases.

- N_2O concentrations upstream and downstream of the SCR reactors were low, with the observed range varying from 1 to about 3 ppmv. No consistent trend toward increasing or decreasing concentration across the SCR reactors was observed; in many cases, there was no significant change in the N_2O concentrations between SCR reactor inlet and outlet.

- An apparent increase in HCl concentration across the SCR reactors appeared to be an artifact of the sampling methods used; flue gas particulates were not collected at the SCR reactor inlets, where a portion of the chloride was probably present in the form of solid-phase salts (e.g., ammonium chloride).

- The particulate matter loading was apparently higher at the SCR reactor outlets than at the hot-side ESP inlet located upstream of the reactors. However, the measured ESP inlet loading appeared to have been low, based on subsequent measurements made in the economizer bypass duct at low boiler load conditions. As expected, the average loading was higher at higher boiler load conditions than at low load (i.e., averages of 3.9 and 3.5 grains/dscf, respectively).

- Good agreement was observed in both particulate matter size distribution and composition at the main reactor inlet and downstream of the last catalyst level for each of the SCR reactors.

- Based on the results of the Toxicity Characteristic Leaching Procedure (TCLP) analyses of the fly ash samples obtained at the SCR reactor inlet, reactor outlet, or air preheater outlet, no significant change in characteristics was noted across the SCR reactors, and none of these solids would be classified as hazardous under Title III of RCRA, with respect to the toxic metals.

- As expected, the SCR demonstration project did not have any detectable impact on the measured water quality parameters for the ash pond discharge stream.

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1.0 Introduction

The purpose of the Clean Coal Technology (CCT) project conducted at Plant Crist was to demonstrate the use of selective catalytic reduction (SCR) to reduce NO_x emissions from pulverized-coal utility boilers using high-sulfur U.S. coal.

In response to procedures developed by the Department of Energy to comply with the National Environmental Policy Act (NEPA) requirements, Southern Company Services was required to develop and implement an Environmental Monitoring Plan (EMP) for the Selective Catalytic Reduction demonstration project at Plant Crist (1). The EMP was developed to fulfill the following specific objectives:

- To provide monitoring data to fulfill project-related environmental compliance requirements of local, state, and federal regulatory agencies:
- To define and describe supplemental monitoring activities;
- To ensure that emissions and environmental impacts were consistent with projections provided in NEPA documents; and
- To develop an environmental record that can be used for future replication of the subject technology.

This report presents and discusses the data obtained during the SCR demonstration project in fulfillment of the EMP objectives.

1.1 SCR Demonstration Facility Description

The SCR test facility was built in and around the ductwork of Plant Crist Unit 5. A simplified schematic flow diagram for the SCR test facility is shown in Figure 1-1.

The SCR facility consisted of three large SCR reactors, each with a design capacity of 5,000 standard cubic feet per minute (scfm) of flue gas, and six smaller reactors, each with a design capacity of 400 scfm of flue gas. With all of the SCR reactors in operation, the total equivalent capacity of the SCR project was 8.7 MW (representing approximately 10% of the full-load capacity of Unit 5 and less than 1% of the entire plant's flue gas volume).

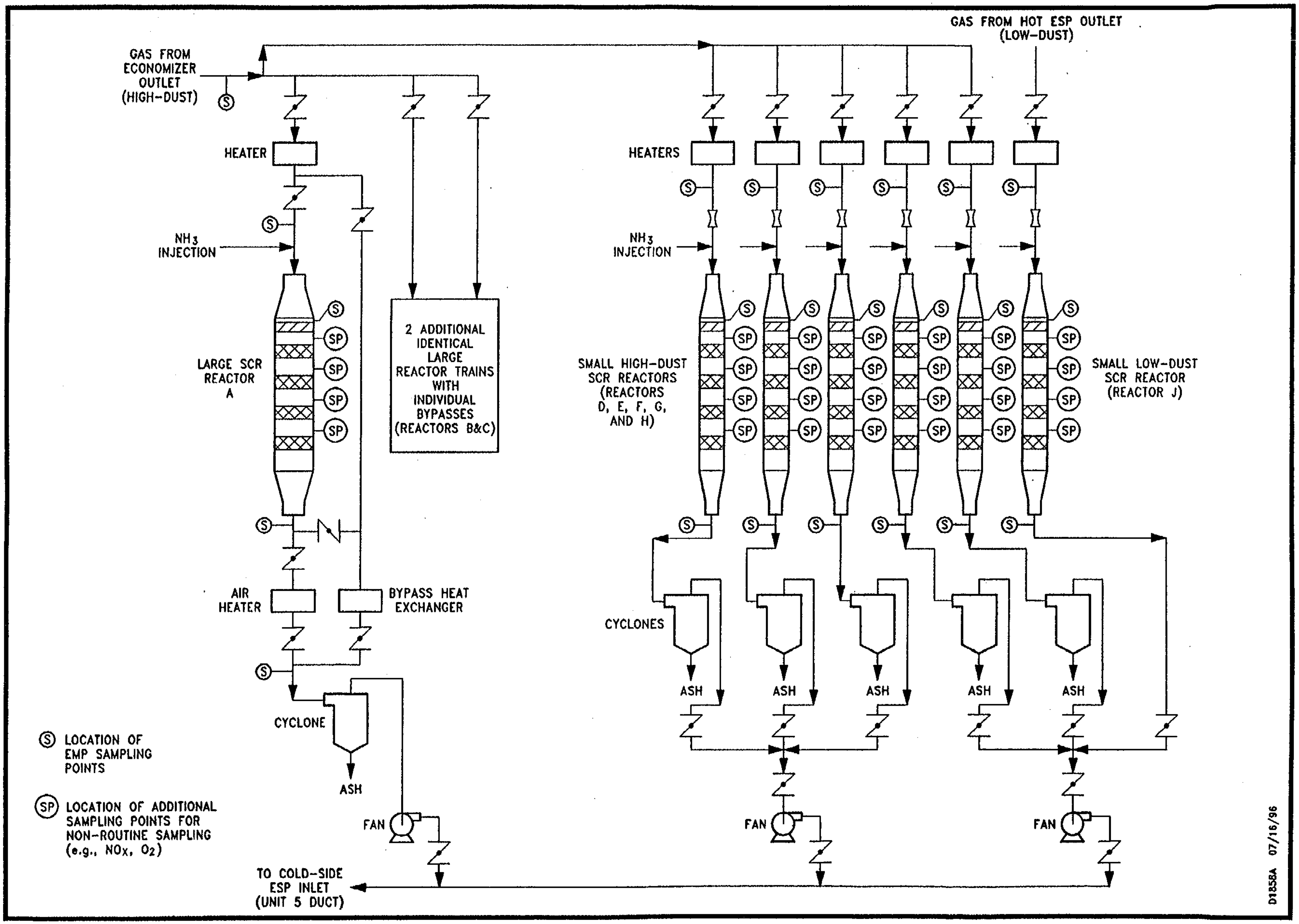

Figure 1-1. Prototype SCR Demonstration Facility—Process Flow Diagram

The SCR test facility had the capability of extracting representative flue gas from either of two main power plant duct locations at Plant Crist:

- Unit 5 upstream of the hot-side electrostatic precipitator (ESP) (i.e., Unit 5 high dust); and
- Unit 5 downstream of the hot-side ESP (Unit 5 low dust).

Flue gas extraction was accomplished by inserting gas sampling scoops into the flue gas stream from the host boiler. The high-dust extracted gas supplied the three large reactors (Reactors A, B, and C) and five of the small reactors (Reactors D, E, F, G, and H). The low-dust stream supplied a single small reactor (Reactor J). The high-dust stream was divided at the main extraction scoop header, and the gas was supplied to each of the eight high-dust reactors via individual ducts.

Before the gas entered the SCR reactors, ammonia was injected into the flue gas to facilitate the NO_x reduction process. The NO_x removal efficiency and other parameters were measured before the treated gas was discharged into the main flue gas duct upstream of the existing cold-side precipitators for particulate removal and discharge to the atmosphere.

Flue gas flow rates through each reactor were monitored by in-line, full-flow venturis placed downstream of electric in-duct heaters. These in-duct heaters were included so the inlet gas temperatures could be controlled to specified levels. Thus, each venturi measured gas flow under reasonably constant gas temperature conditions. The heaters were required since the boiler economizer outlet temperature varied with boiler load and ranged between 590 and 690°F, while the design temperature for the SCR unit was 700°F (although tests were conducted at higher and lower temperatures).

Figure 1-2 shows a simplified layout of the SCR test facility. For both the large and small reactors, the transition piece from the main supply duct was designed to reduce the gas flow from 60 feet per second (fps) to 14.6 fps, and to assure that the gas velocity was uniform across the reactor cross-section. The dimensions of the large reactors were approximately 3'6" x 4'6" x 40'0" (length). The small reactors were approximately 1'1" square x 40'0" (length).

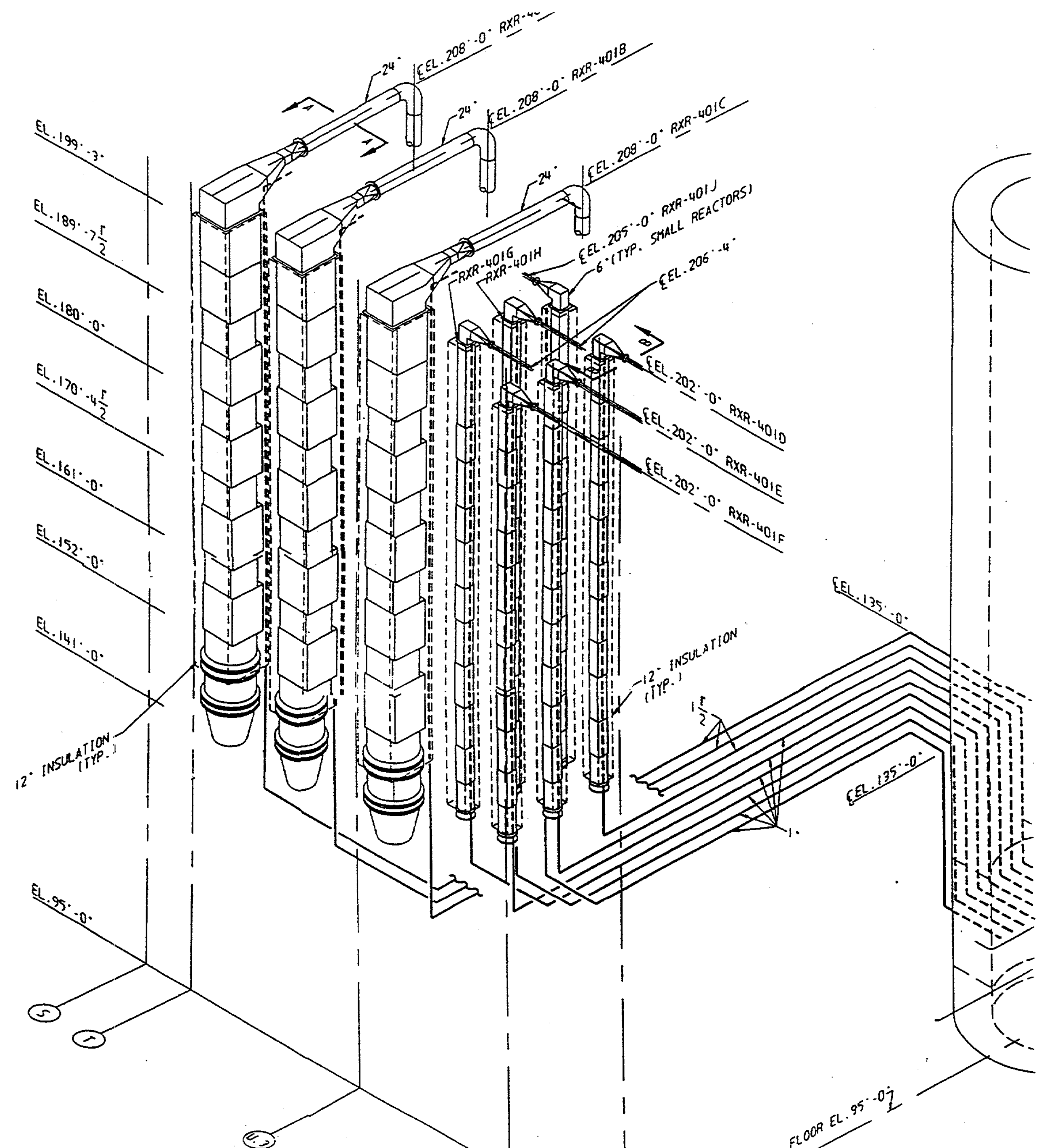

Figure 1-2. Basic Layout of the SCR Test Facility

As the gas exited the large reactors, it passed through a transition piece at the SCR reactor outlet and directly into the pilot air preheaters. Pilot air preheaters on two of the large reactors (Reactors A and B) simulated full-scale utility rotary air heaters of slightly different designs. The air heater on the third large reactor (Reactor C) was a heat pipe design.

As the flue gas exited each air heater, it passed through a cyclone for particulate removal (to protect the ID fans), a louvered damper (used to modulate flow based on venturi flow signals), and an ID fan. The ID fan could operate between 3,000 and 7,500 scfm (with a design, continuous operating capacity of 5,000 scfm). The flue gas exiting the small reactors passed through cyclones and louvered dampers to ID fans. No air heaters were provided on the small reactors.

The SCR test facility evaluated commercially-available SCR catalysts obtained from world-wide vendors. Details of the catalysts used in each reactor, their vendors, and catalyst configurations are provided in the project's final report prepared by Southern Company Services, Inc. (2).

1.2 Project Description

The operational and testing phase of the SCR demonstration project was divided into four tasks, as follows:

- Task 1 (commissioning without catalysts and without ammonia injection) involved calibration of the venturi flow controllers upstream of each reactor; measurement of particle mass concentration at the inlet and outlet of the Unit 5 hot-side electrostatic precipitator (ESP) at high- and low-load conditions; measurement of the particle mass loadings in the economizer bypass duct at low load, and verification of the similarity of the particulate loadings, size distributions, and composition of the fly ash collected inside the eight high-dust reactors; measurement of baseline gas-phase flue gas composition; and determination of the degree of conversion of SO_2 to SO_3 across one large and one small reactor.

- Task 2 (commissioning without catalysts and with ammonia injection) was conducted to verify ammonia flow control, establish an ammonia mass balance, and measure ammonia loss in the absence of catalyst. Ammonia loss was measured across one large reactor and one small reactor.

- Task 3A (commissioning with catalysts and without ammonia injection) was combined with Task 3B (Preliminary Parametric Tests). Tests were conducted to examine the degree of conversion of SO_2 to SO_3 across the SCR reactors with catalysts installed and to evaluate the initial performance of the reactors with catalysts installed and with ammonia injection. Although the SO_2 conversion tests were originally planned without ammonia injection, the tests were actually conducted with ammonia injection.

- Task 4 (Long-Term Parametric Tests) was performed to evaluate the long-term performance of the SCR reactors with catalyst installed and with ammonia injection. The parametric tests included in this Task included measurements of a number of gas-phase constituents at various combinations of flue gas flow rate, temperature, and NH_3/NO_x ratio. When not undergoing parametric tests, each reactor was returned to its baseline operating condition for long-term performance evaluation.

1.3 Report Organization

The remainder of this report is organized as follows:

- Section 2 discusses the planned and actual EMP monitoring for gaseous, aqueous, and solid streams over the course of the SCR demonstration project;
- Section 3 summarizes sampling and analytical methods and discusses exceptions from the methods specified in the EMP;
- Section 4 presents and discusses the gas stream monitoring results;
- Section 5 presents and discusses the aqueous stream monitoring results;
- Section 6 presents and discusses the solid stream monitoring results;
- Health and safety considerations are discussed in Section 7.
- Section 8 discusses EMP-related quality assurance/quality control activities performed during the demonstration project;
- Section 9 summarizes compliance monitoring reporting activities;
- Section 10 presents a summary of results and conclusions based on the EMP monitoring results; and
- Section 11 provides a list of references.

Tables containing the detailed results for each of the streams monitored as part of the EMP are provided in Appendix A.

2.0 EMP Monitoring Summary

EMP monitoring was performed during each of the four operational and testing phase tasks described in Section 1. Table 2-1 summarizes the duration of each of the project tasks.

Key segments of the demonstration project included the five sequences of parametric tests (one during Task 3B and four during Task 4). During the parametric tests, the impacts of SCR reactor operating conditions (i.e., operating temperature, ammonia-to-nitrogen oxide flow ratio, and reactor residence time) were determined for a number of parameters, including NO_x reduction, ammonia slip, and conversion of SO_2 to SO_3. Table 2-2 summarizes the test conditions relative to these parameters for each of the five parametric test sequences. Nitrous oxide and hydrogen chloride concentrations were also measured during tests conducted at SCR reactor baseline operating conditions (i.e., 700°F, design flow rate, 0.8 NH_3 /NO_x ratio).

Tables 2-3, 2-4, and 2-5 present the planned EMP monitoring schedules for gaseous, aqueous, and solid streams, respectively. Due to time and budget constraints, a number of modifications were made to the original EMP monitoring schedule for some parameters. These changes are discussed below.

The number of gaseous stream monitoring data points collected during each of the operational and testing phase tasks (in addition to those parameters measured using continuous on-line monitors) are summarized in Table 2-6. Note that Reactor J was not monitored during either the startup screening tests or the first two parametric test sequences. The Reactor J catalyst was damaged just hours after initial operations began. A replacement catalyst was not installed until several months later. The supplier of catalyst for Reactor H withdrew from the project, and this reactor was not included in subsequent monitoring activities. Additional modifications of the original EMP monitoring schedules included the following:

- SO_2 monitoring at the SCR reactor outlets was conducted during each of the parametric test sequences, rather than just during the initial start-up screening tests.

- N_2O and SO_3 monitoring at the SCR reactor inlets was also not limited to the start-up screening tests, but was performed during 3 of 5 parametric test sequences.

Table 2-1. Demonstration Project Test Sequence

Task Number	Description	Dates
1	Commissioning Without Catalysts and Without Ammonia Injection: • Flow calibration • Particulate matter concentration and particle size distribution measurements • Baseline gas constituent measurements • Fly ash chemical analyses • Trace metals analyses	January - April 1993
2	Commissioning Without Catalysts and With Ammonia Injection: • Verification of ammonia flow control • Ammonia mass balance • Ammonia loss in the absence of catalyst	May - June 1993
3	3A: Commissioning With Catalysts and Without Ammonia Injection • SO_2 oxidation tests* 3B: Preliminary Parametric Tests (Test Sequence 1)	June- December 1993
4	Long-Term Parametric Tests • Test Sequence 2 • Test Sequence 3 • Test Sequence 4 • Test Sequence 5	 January - April 1994 June - September 1994 October 1994 - January 1995 May - July 1995

*These tests were actually performed with ammonia injection.

Table 2-2. Plant Crist SCR Demonstration: Parametric Test Conditions

Test Condition Code No.[a]	Target Test Conditions			Parametric Test Sequence				
	Flue Gas Temp., °F	Flue Gas Flow Rate, Fraction of Design	NH_3/NO_x Ratio	1	2	3	4	5
1	620	0.6	0.6	S	—[b]	—	—	—
2	620	0.6	0.8	—	S	A	A,N	A,N
4	620	0.6	1.0	S	—	—	—	—
6	620	1.0	0.6	—	—	A,N	A,N	A,N
7	620	1.0	0.8	—	A	A,N	A,N	A,N
9	620	1.0	1.0	—	—	A,N	A,N	A,N
11	620	1.5	0.6	S	—	—	—	—
12	620	1.5	0.8	—	A	—	—	—
14	620	1.5	1.0	A,S	A	A,N	A,N	A,N
16	700	0.6	0.6	A	—	—	—	—
17	700	0.6	0.8	—	S	—	—	—
19	700	0.6	1.0	A	—	—	—	—
21	700	1.0	0.6	—	—	A,N	A,N	A,N
22	700	1.0	0.8	A,S	A,S	A,N,S	A,N,S	A,N,S
24	700	1.0	1.0	—	—	A,N	A,N	A,N
26	700	1.5	0.6	A	—	A,N	A,N	A,N
27	700	1.5	0.8	—	A,S	A,N	A,N,S	A,N
29	700	1.5	1.0	—	—	A,N	A,N	A,N
31	750	0.6	0.6	S	—	—	—	—
32	750	0.6	0.8	—	S	—	—	—
34	750	0.6	1.0	S	—	—	—	—
36	750	1.0	0.6	—	—	A,N	A,N	A,N
37	750	1.0	0.8	—	S	A,N,S	A,N,S	A,N
39	750	1.0	1.0	—	—	A,N	A,N	A,N
41	750	1.5	0.6	S	—	—	—	—
42	750	1.5	0.8	—	S	—	—	—
44	750	1.5	1.0	S	—	—	—	—

Key: A = NH_3 slip
N = NO_x reduction
S = SO_2/SO_3

[a] Code indicates test conditions, not test sequence.

[B] Dash indicates that test was not scheduled or performed.

Table 2-3. Gaseous Streams: Integrated Monitoring Schedule SCR Demonstration Project (Revised)

Parameter	Monitoring Schedule [a,b]		
	SCR Inlet Gas (common to all reactors)	SCR Outlet Gas (for each reactor)	Air Preheater Outlet Gas
SO_2	COM	T	
CO	COM		
N_2O	T	T	
NO_x	COM	COM*	
O_2	COM	COM	COM [c]
SO_3	S	T	
NH_3	T	T	
HCl	S	T	
Particulate Matter:			
Loading	S	P**	
Size Distribution	S	P**	
Composition [d]	S	P**	
TCLP [e]	P*** (composite grab sample from ESP hopper)	P*** (composite grab sample from 5 small reactor cyclones)	P*** (composite grab sample from 3 large reactor cyclones)

[a] Monitoring frequency: T = one time per parametric test and one time during initial start-up screening tests (for NH_3 and SO_3, samples will be collected in duplicate and analyzed in triplicate); S = one time during start-up screening tests; and P = periodically during the project.

[b] Some of these data will be available from process data collection.

[c] O_2 was not measured at the Reactor C air preheater outlet since no inleakage was expected across the heat pipe.

[d] Includes ash mineral analysis (iron, aluminum, silicon, calcium, magnesium, sodium, potassium, and titanium), ammonium bisulfate, chloride, and metals.

[e] For TCLP determination, all reactors were sampled at their respective ash hoppers. On the large reactors, this was done downstream of the air preheater.

COM = Continuous on-line monitor

* Monitored continuously on a time-share basis.
**Estimated semi-annual basis.
***One time during initial screening test, annually thereafter.

[All monitoring shown is supplemental.]

Table 2-4. Aqueous Streams: Integrated Monitoring Schedule SCR Demonstration Project

Parameter	Monitoring Schedule [a,b]	
	Air Preheater Wash Water [c,d]	Ash Pond Discharge
Total Suspended Solids	1/Q[s]	1/W[c]
Total Dissolved Solids	1/Q[s]	
pH	1/Q[s]	1/W[c]
Oil and Grease	1/Q[s]	1/2W[c]
Chloride	1/Q[s]	
NH_4HSO_4 (as $SO_4^{=}$)	1/Q[s]	
Total Metals:		
Aluminum, Copper, Mercury, Arsenic, Iron, Nickel, Cadmium, Lead, Selenium, Chromium, Manganese, Zinc	1/Q[s]	

[a] Monitoring frequency: 1/W = once per week; 1/2W = once every two weeks; and 1/Q = once per calendar quarter.

[b] Letter within brackets indicates monitoring type: [c] = compliance monitoring and [s] = supplemental monitoring for duration of SCR demonstration project only.

[c] Refers only to the air preheater wash that is associated with the demonstration unit.

[d] Wash water will be monitored during each wash cycle, up to four times per year. The actual sampling frequency will depend on the required washing frequency.

Table 2-5. Solid Streams: Integrated Monitoring Schedule SCR Demonstration Project

Parameter	Monitoring Schedule [a,b] Coal Feed
Ultimate Analysis	1/Q[s]
Chlorine	1/Q[s]

[a] Monitoring frequency: 1/Q = once per quarter.

[b] Letter within brackets indicates monitoring type: [s] = supplemental monitoring for duration of SCR demonstration project.

Table 2-6. Gaseous Stream Monitoring Summary: Number of Data Points Collected for Non-Continuous Parameters

Monitored Parameter	Monitoring Location—SCR Reactor									
	ESP Inlet	A	B	C	D	E	F	G	H	J
Startup Screening Tests (Tasks 1 - 3A)										
SO_2/SO_3 (Oxidation Tests)	—[a]	9	11	15	—	—	—	—	—	—
NH_3 (Loss Tests)	—	—	4	—	—	4	—	—	—	—
PM Loading	2	2	2	2	2	2	2	2	2	—
PM Size Distribution	2	2	2	2	2	2	2	2	2	—
PM Composition	2	1	1	—	—	—	—	—	—	—
TCLP	1	2	2	2	1	1	1	1	1	—
Parametric Test Sequence 1										
NH_3 (Inlet & Outlet)	—	5	6	7	2	2	2	—	—	—
SO_2/SO_3 (Outlet)	—	9	9	9	5	5	5	—	—	—
HCl (Outlet)	—	1	1	3	1	1	1	—	—	—
N_2O (Inlet & Outlet)	—	0	0	0	0	0	0	—	—	—
Parametric Test Sequence 2										
NH_3 (Inlet & Outlet)	—	8	8	7	7	8	8	6	—	—
SO_2/SO_3 (Outlet)	—	7	7	7	7	7	7	7	—	—
HCl (Outlet)	—	1	1	1	1	1	1	1	—	—
N_2O (Inlet & Outlet)	—	1	1	1	1	1	1	1	—	—
Parametric Test Sequence 3										
NO_x (Inlet & Outlet)	—	9	14	9	17	14	17	14	—	11
NH_3 (Inlet & Outlet)	—	14	14	14	17	14	17	14	—	11
SO_2/SO_3 (Inlet & Outlet)	—	2	2	2	2	2	2	2	—	1
HCl (Outlet)	—	1	1	1	1	1	1	1	—	1
N_2O (Inlet & Outlet)	—	0	0	0	0	0	0	0	—	0
Parametric Test Sequence 4										
NO_x (Inlet & Outlet)	—	14	14	12	14	15	15	14	—	14
NH_3 (Inlet & Outlet)	—	14	14	14	14	15	15	14	—	11
SO_2/SO_3 (Inlet & Outlet)	—	3	3	3	3	3	3	3	—	3
HCl (Inlet & Outlet)	—	1	1	1	1	1	1	1	—	1
N_2O (Inlet & Outlet)	—	1	1	1	1	1	1	1	—	1

Table 2-6 (continued)

Monitored Parameter	Monitoring Location—SCR Reactor									
	ESP Inlet	A	B	C	D	E	F	G	H	J
Parametric Test Sequence 5										
NO_x (Inlet & Outlet)	—	14	15	14	14	14	14	14	—	14
NH_3 (Inlet & Outlet)	—	14	15	14	14	14	14	14	—	14
SO_2/SO_3 (Inlet & Outlet)	—	1	1	1	1	1	1	1	—	1
HCl (Inlet & Outlet)	—	1	—	—	—	—	—	—	—	—
N_2O (Inlet & Outlet)	—	1	1	1	1	1	1	1	—	1
Periodic Monitoring (following start-up screening tests)										
PM Loading	—	3	4	3	3	3	3	1	—	—
Ash Composition	—	1	1	1	—	—	—	—	—	—
TCLP	2	2	2	2	2	2	2	2	1	—

[a] Dash indicates that test was not scheduled or performed.

- HCl monitoring at the SCR reactor inlets was performed during one of the parametric test sequences for all operating reactors and for one reactor during another test sequence.

- In addition to the data provided by continuous on-line monitors, reactor inlet and outlet stream samples were collected and analyzed for SO_2 and NO_x.

- Particulate matter (PM) loading, composition, and size distribution were measured less frequently than shown in the EMP. Particulate matter size distributions were only measured during initial screening tests (at two boiler load levels). Loading and composition were conducted throughout the testing phase, but somewhat less frequently than the estimated semi-annual basis shown in the EMP.

Aqueous stream compliance monitoring was conducted for the ash pond discharge at the frequencies required by Plant Crist's discharge permit. Analytical results of air preheater wash water were only available from one wash cycle, and only a limited suite of parameters were measured, including pH, iron, fluoride, chloride, and sulfate.

Ultimate analyses and chlorine content were obtained using monthly coal feed composite samples rather than quarterly composites as shown in the EMP.

3.0 Sampling and Analytical Methods

The sampling and analytical methods used in implementing the environmental monitoring program at Plant Crist are summarized in this section of the report. Descriptions of the sampling and analytical methods were provided in the QA/QC Plan developed as part of the project EMP (1).

3.1 Sampling Methods

The sampling methods used during the environmental monitoring activities are summarized in Tables 3-1, 3-2, and 3-3. There were no changes from the planned methods as outlined in the EMP.

3.2 Analytical Methods

Analytical methods used in analyzing environmental samples are listed in Tables 3-1, 3-2, and 3-3. The methods presented in the EMP were used with the following exceptions:

- A non-dispersive type IR analyzer was used for CO analyses, not a "Fuji CO analyzer."
- The NO_x analyzer was a chemiluminescence analyzer but not "TECO."
- Oxygen was measured using a zirconium oxide cell, not a "Thermox O_2 analyzer."

In the original proposal, the Fuji CO analyzer, the TECO analyzer, and the Thermox O_2 analyzer were proposed as examples of instruments that would provide the required analyses. During the design stage of the project, however, the project analytical requirements were reviewed in a very thorough manner. As a result, the alternate instruments listed above were selected as the best methods for the required analyses.

Other exceptions include:

- SO_3, HCl, and NH_3 were measured in the SCR reactor air preheater outlet steams, in addition to the SCR reactor inlet and outlet streams.
- O_2 was measured in the air preheater outlet of Reactors A and B, but not that following Reactor C, which used a heat pipe for which no air inleakage was expected.

Table 3-1. Sampling and Analytical Methods Summary: Gaseous Streams (Revised 7/1/96)

Parameter	Sampling Method	Analytical Method/Instrument	Streams Included [a]
SO_2	GAS [b]	UV Spectrophotometer	a
CO	GAS	Non-dispersive IR Analyzer	a
N_2O	Grab[c]	GC w/ECD	a, b
NO_x	GAS	Chemiluminescence Analyzer	a, b
O_2	GAS	Zirconium Oxide Cell	a, b, c
SO_3	Controlled Condensation	Impinger, IC[d]	a, b, c
HCl	Impinger	Impinger, ISE[e]/IC[d]	a, b, c
NH_3	Impinger	Impinger, ISE[e]	a, b, c
Particulate Matter:			
Loading	EPA Method 17	Gravimetric	a, b
Size Distribution	Impactors/Cyclones[f]	Gravimetric	a, b
Composition:	Method 17 Catch		a, b
Ash Minerals		Fusion, dissolution, AA/ICP-AES (ASTM D3682)	
NH_4HSO_4		X-ray diffraction	
Chloride		Digestion, Ion Chromatography (EPA 300.0)	
Metals		Digestion, AA/ICP-AES (EPA 206.3, 213.2, 239.2, 245.1, 270.3, 200.7)	
TCLP		Leaching, GC and AA/ICP-AES (EPA 1311)	

[a] Stream Identification: a = SCR reactor inlet (common to all high-dust reactors); b = SCR reactor outlet (for each reactor); and c = air preheater outlet (for each reactor for SO_3, HCl, and NH_3; Reactors A and B for O_2).
[b] GAS = Extractive gas analysis system
[c] Grab sample for N_2O determination was carefully conditioned by passing through phosphorus pentoxide (to remove water) and sodium bicarbonate (to remove SO_2).
[d] IC = Ion chromatography.
[e] ISE = Ion specific electrode.
[f] A = Shimadzu and University of Washington cascade impactors and five-stage cyclones.

Table 3-2. Sampling and Analytical Methods: Aqueous Streams (Revised 12/9/92)

Parameter	Sampling Method	Analytical Method	Streams Included [a]
Total Suspended Solids	Grab	Filtration/Drying/Gravimetric (EPA 160.2)	a, w
Total Dissolved Solids	Grab	Filtration/Evaporation/Gravimetric (EPA 160.1)	w
pH	Grab	Electrometric (EPA 150.1)	a
Oil and Grease	Grab	Freon Extraction/Gravimetric (EPA 413.1)	a
Chloride	Grab	Titration (EPA 325.3)	w
Ammonium Bisulfate (as $SO_4^=$)	Grab	Ion Chromatography (EPA 300.0)	w
Metals	Grab	Dissolution, AA/ICP-AES [b] (EPA 206.3, 213.2, 239.2, 245.1, 270.3, 200.7)	w

[a] Stream identification: a = ash pond discharge and w = air preheater wash water.

[b] Analytical methods: AA = atomic absorption and ICP-AES = inductively coupled plasma argon emission spectroscopy.

Table 3-3. Sampling and Analytical Methods: Solid Streams (Revised 7/1/96)

Parameter	Sampling Method	Analytical Method	Streams Included [a]
Ultimate Analysis	Grab/Composite	Combustion/Gravimetric/ Titration (ASTM D3180)	f
Chlorine	Grab/Composite	Fusion/IC [b] or Titration (ASTM D4208)	f

[a] Stream identification: f = coal feed.

[b] IC = Ion chromatography.

- ASTM methods other than those shown in the EMP were used for the feed coal analyses: ASTM D3180 was used for ultimate analyses, while ASTM D4208 was used for the determination of chlorine concentration.

These alternate methods were equivalent or superior to the methods listed in the EMP (1).

4.0 Gaseous Stream Monitoring Results

Gaseous stream monitoring results are summarized and discussed in this section of the report. The results of parametric and long-term monitoring are discussed separately. Tables containing the detailed monitoring data are provided in Appendix A. The data were taken from Southern Company Services' final report (2) and Southern Research Institute's (SRI) interim reports (3,4,5,6,7,8,9,10).

4.1 Parametric Test Results

The impacts of SCR reactor operating conditions on flue gas constituents were investigated during the five parametric test sequences that were conducted over the course of the demonstration program. This section discusses the monitoring results for nitrogen oxides, ammonia, sulfur oxides, nitrous oxide, hydrogen chloride, and particulate matter.

4.1.1 Nitrogen Oxides (NO_x)

NO_x reductions achieved by each of the SCR reactors were calculated using SRI test data from parametric test sequences 3, 4, and 5, for which both reactor inlet and outlet NO_x concentrations were available in SRI's interim reports. A summary of the mean apparent NO_x reductions measured during the parametric testing is presented in Table 4-1. The NO_x reductions shown have not been corrected for factors such as oxygen in-leakage and, therefore, do not match exactly the data used for evaluating catalyst performance or corrected data shown in the project quarterly and final reports. Also note that in some cases the actual reactor operating conditions varied significantly from the target conditions shown in Table 4-1.

Figures 4-1 through 4-6 are plots of apparent NO_x reduction showing the effects of reactor operating temperature, NH_3/NO_x ratio, and gas residence time (which is inversely proportional to gas flow rate). These figures are based on the mean NO_x removals when replicate tests were conducted for a given set of operating conditions. In general, changes to the major SCR reactor operating parameters had the following impacts:

- Increasing the NH_3/NO_x ratio increased NO_x reduction efficiency;
- Increasing reactor residence time (i.e., reducing gas throughput) increased NO_x reduction efficiency; and

Table 4-1. SCR Reactor Mean Apparent NO_x Reductions Across SCR Reactors During Parametric Tests

Target Reactor Operating Conditions				Mean Apparent NO_x Reduction, Percent							
				Reactor ID							
Test Condition	Temp., °F	Gas Flow/ Design Flow	NH_3/NO_x	A	B	C	D	E	F	G	J
2	620	0.6	0.8	79.1	84.2	93.3	96.7	80.0	96.0	82.5	61.5
6	620	1.0	0.6	71.2	68.6	82.6	84.6	62.0	76.0	66.3	51.2
7	620	1.0	0.8	84.5	87.3	95.3	91.2	75.9	87.3	84.1	67.6
9	620	1.0	1.0	94.1	99.2	99.1	92.0	87.5	92.1	84.1	76.4
14	620	1.5	1.0	89.8	97.5	96.0	85.5	89.9	90.6	85.1	77.8
21	700	1.0	0.6	71.6	69.0	70.5	82.7	74.1	77.5	67.7	56.0
22	700	1.0	0.8	80.8	87.3	88.8	92.3	84.5	82.9	82.4	65.6
24	700	1.0	1.0	88.7	99.8	98.3	94.7	93.9	91.7	85.7	85.7
26	700	1.5	0.6	64.8	66.9	69.5	81.3	71.7	70.6	65.3	55.9
27	700	1.5	0.8	71.0	77.2	89.6	89.6	84.3	81.0	77.4	70.6
29	700	1.5	1.0	90.9	96.0	99.2	92.4	92.9	89.6	88.8	85.4
36	750	1.0	0.6	61.8	69.2	72.9	80.9	72.1	73.6	64.3	58.0
37	750	1.0	0.8	79.6	83.3	92.0	88.7	85.0	83.2	74.0	67.6
39	750	1.0	1.0	90.5	97.1	96.8	94.6	89.2	94.3	87.1	82.2

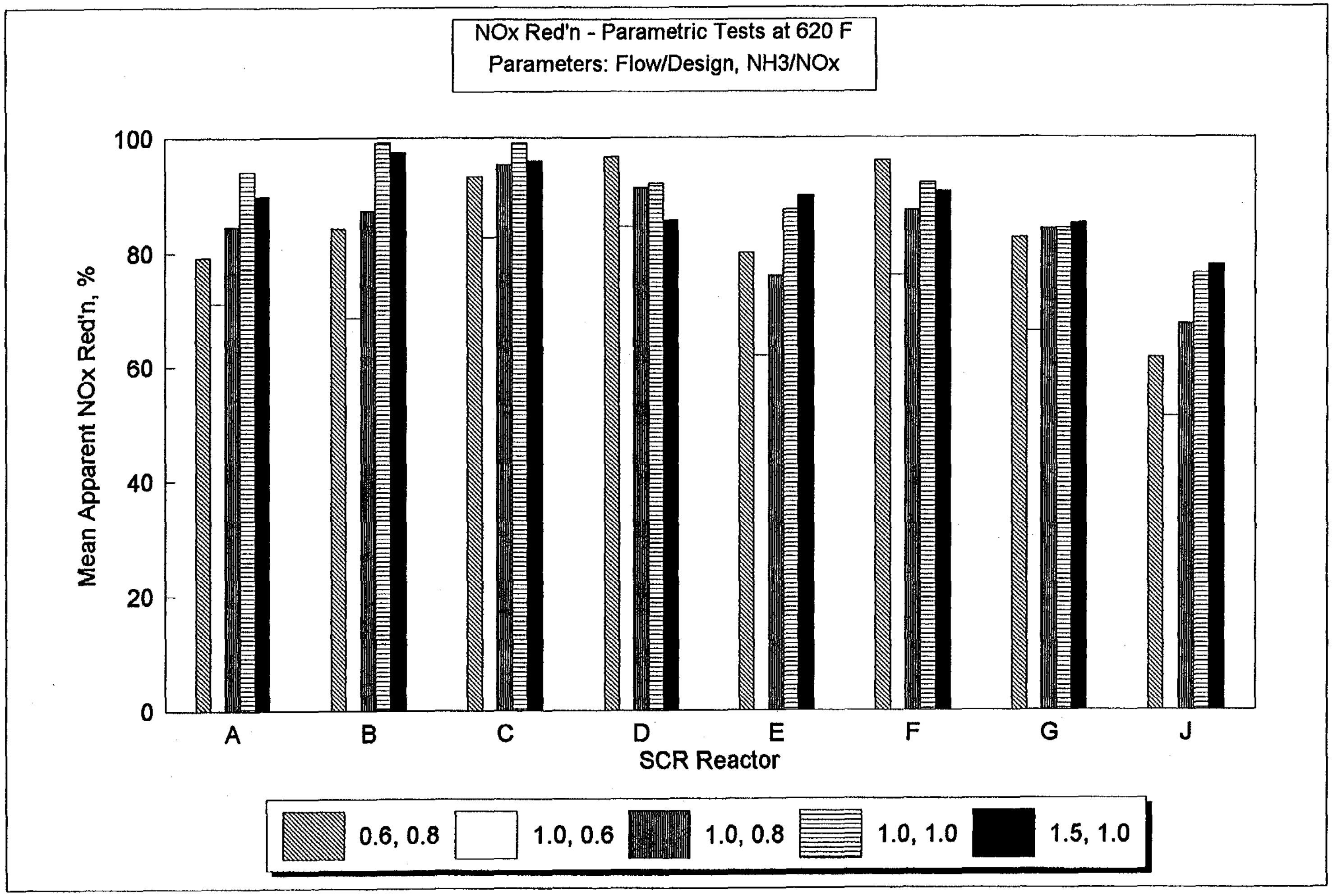

Figure 4-1. Impact of Gas Flow Rate and NH_3/NO_x Ratio on NO_x Reduction: Parametric Tests at 620°F

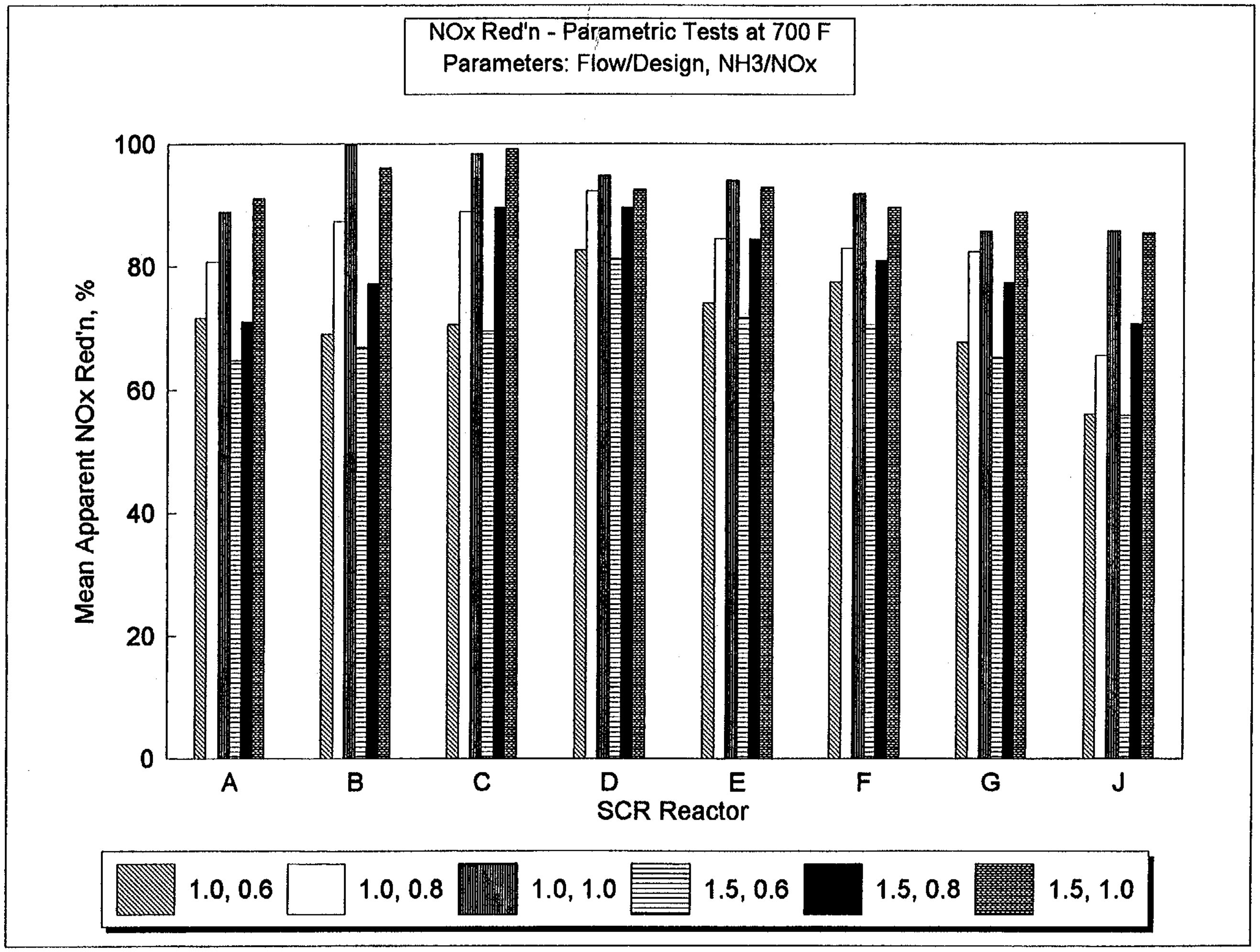

Figure 4-2. Impact of Gas Flow Rate and NH_3/NO_x Ratio on NO_x Reduction: Parametric Tests at 700°F

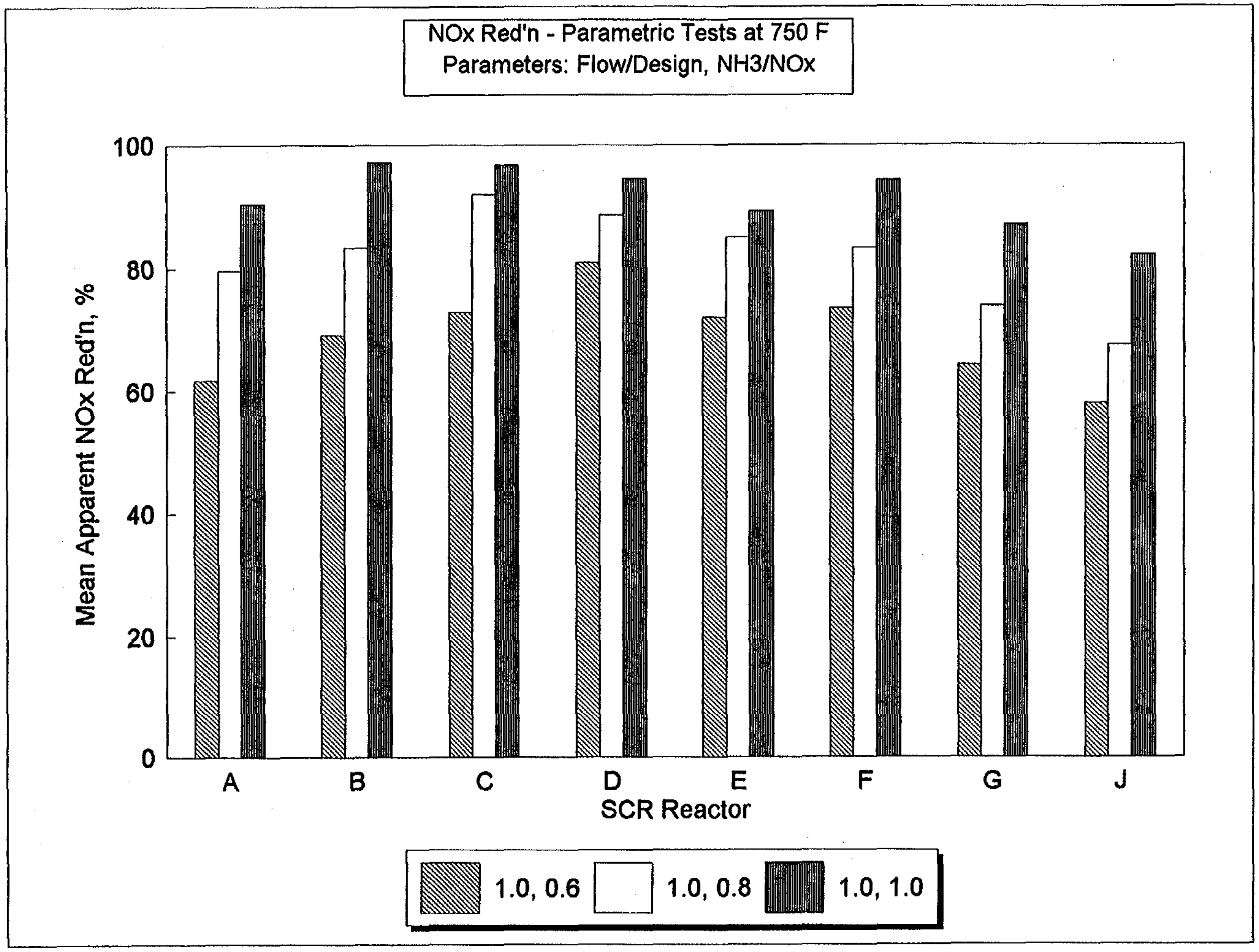

Figure 4-3. Impact of Gas Flow Rate and NH_3/NO_x Ratio on NO_x Reduction: Parametric Tests at 750°F

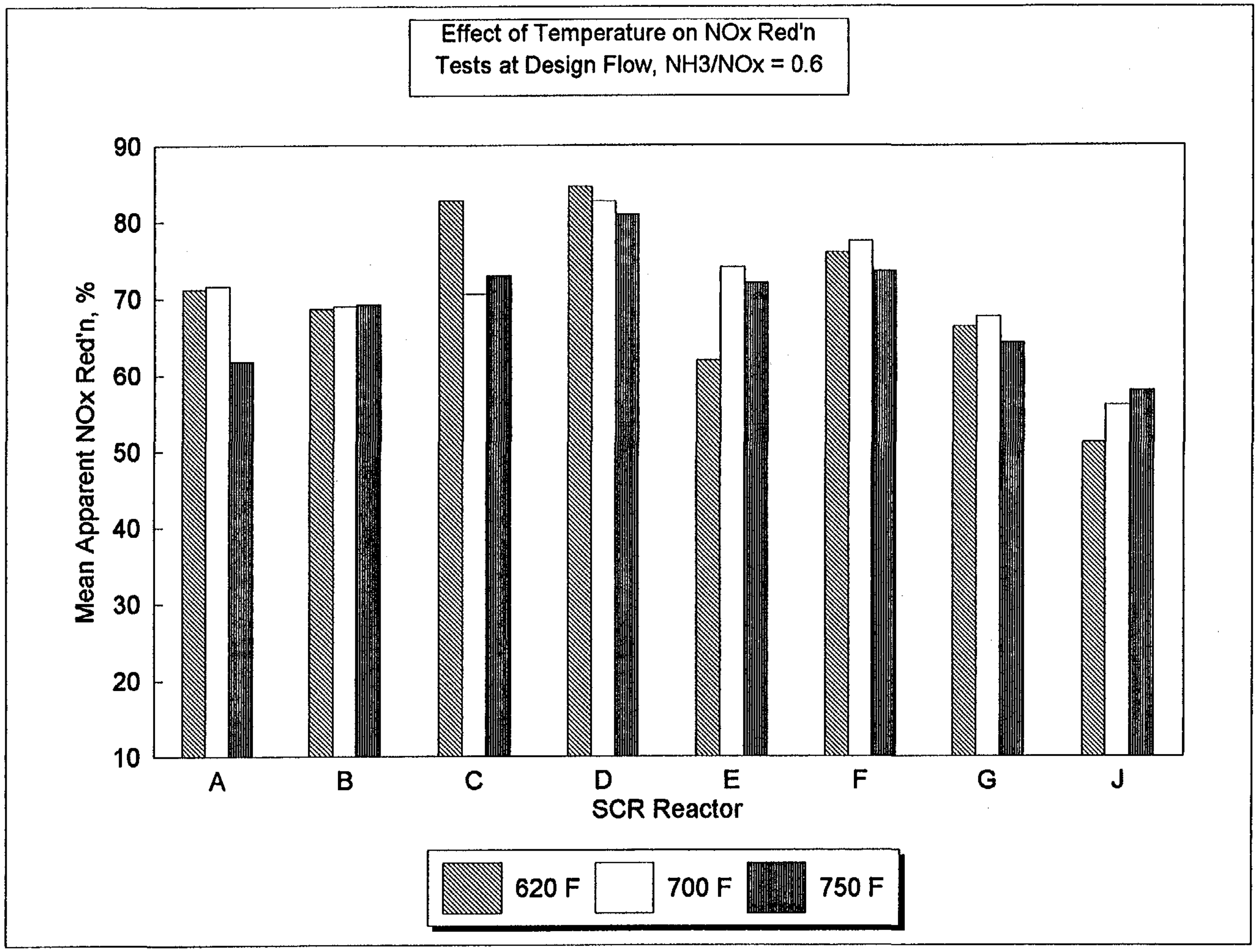

Figure 4-4. Impact of Reactor Operating Temperature on NO_x Reduction: Parametric Tests at Design Flow Rate and NH_3/NO_x Ratio = 0.6

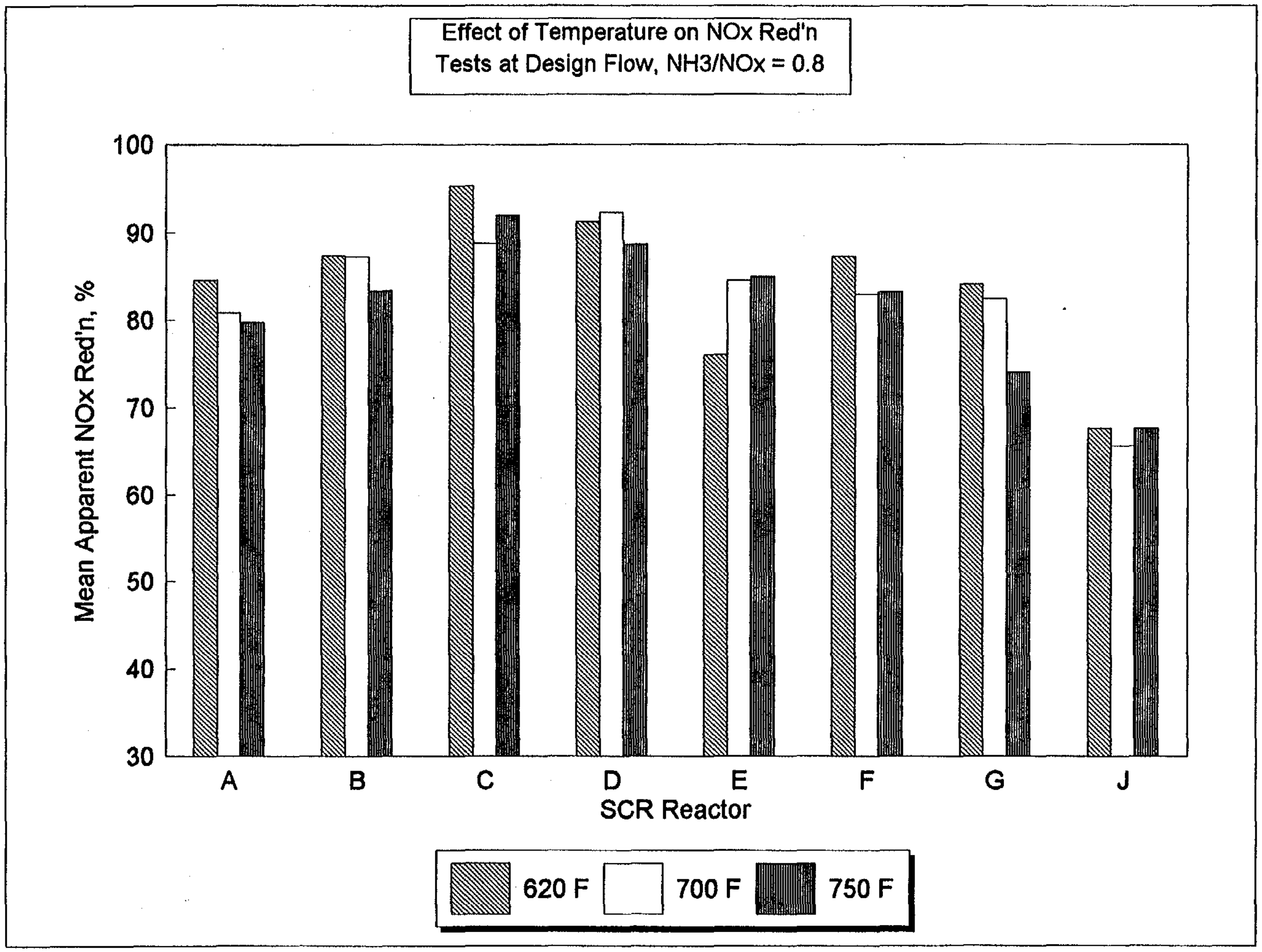

Figure 4-5. Impact of Reactor Operating Temperature on NO_x Reduction: Parametric Tests at Design Flow Rate and NH_3/NO_x Ratio = 0.8

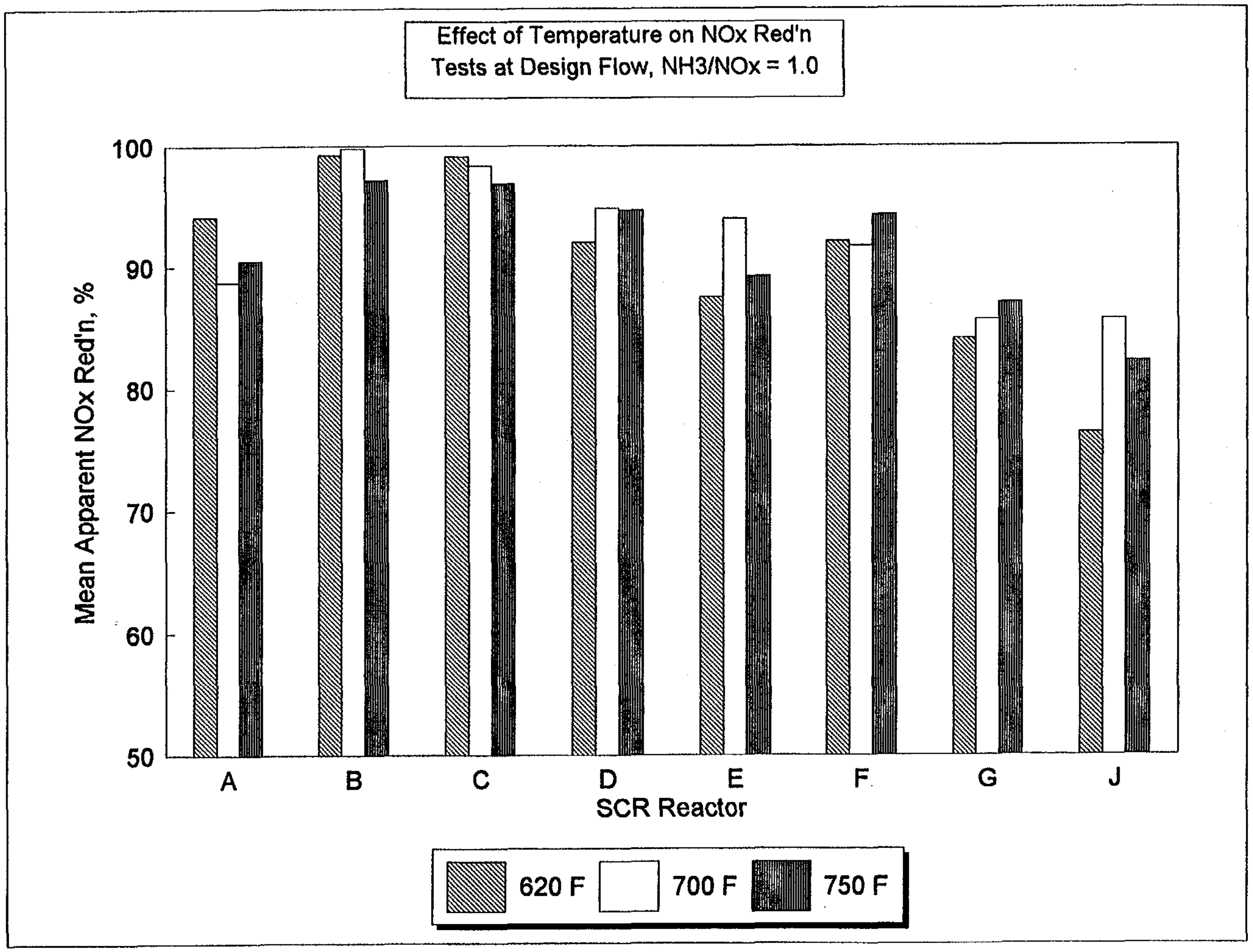

Figure 4-6. Impact of Reactor Operating Temperature on NO_x Reduction: Parametric Tests at Design Flow Rate and NH_3/NO_x Ratio = 1.0

- Within the range of test temperatures, there was no clearly consistent impact of temperature on NO_x reduction efficiency.

4.1.2 Ammonia (NH_3)

The demonstration program included (1) investigations of possible gas-phase reactions of ammonia with other species in the flue gas and (2) the impact of SCR reactor operating conditions on ammonia slip (i.e., the amount of ammonia in the reactor outlet gas).

As part of the SCR reactor commissioning phase, the possibility of ammonia loss across empty SCR reactors, which might have occurred because of gas-phase reactions with oxygen, nitrogen oxides, or sulfur trioxide, was investigated. Simultaneous ammonia concentration measurements were made upstream and downstream of a single large reactor (B) and a single small reactor (E) at four different operating conditions. Temperature and flue gas flow rate were varied in these tests; the NH_3/NO_x ratio was 0.8 for all tests. The results of these tests are shown in Figures 4-7 and 4-8. Within the limits of the measurement technique used, no significant ammonia loss in the absence of catalyst was detected across either reactor.

Measurements were made during both preliminary and long-term parametric tests to determine the impact of SCR reactor operating conditions on ammonia slip across the SCR reactors. The results of these tests are summarized in Table 4-2. Bar graphs of ammonia slip at various target reactor operating conditions are provided in Figures 4-9 through 4-15. In some cases, deviations from the target reactor operating conditions led to higher ammonia slip concentrations. The following general conclusions can be drawn from these data:

- Ammonia slip generally increased at higher NH_3/NO_x ratio.
- Ammonia slip generally increased as the reactor residence time decreased (i.e., as the flue gas flow rate increased through the reactors) for a given operating temperature.
- Ammonia slip generally increased as the reactor operating temperature decreased.

4.1.3 Sulfur Dioxide/Sulfur Trioxide (SO_2/SO_3)

SO_2 and SO_3 concentrations in the SCR reactor inlet and outlet streams were measured periodically over the course of the demonstration program. The variation in SCR reactor inlet gas

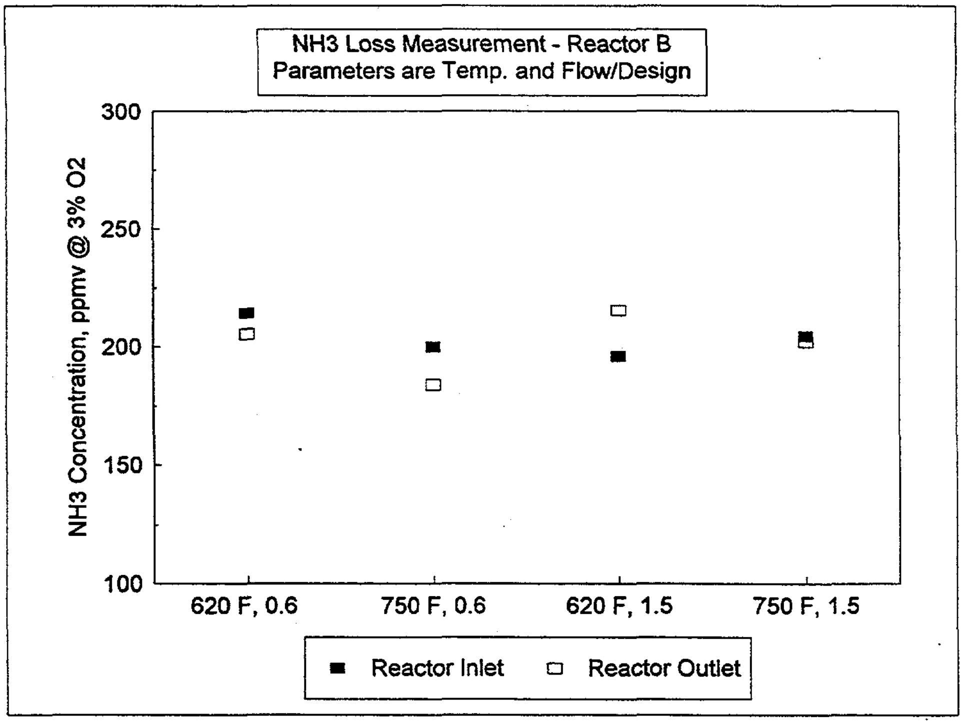

Figure 4-7. Ammonia Loss Across SCR Reactor Without Catalyst: Reactor B

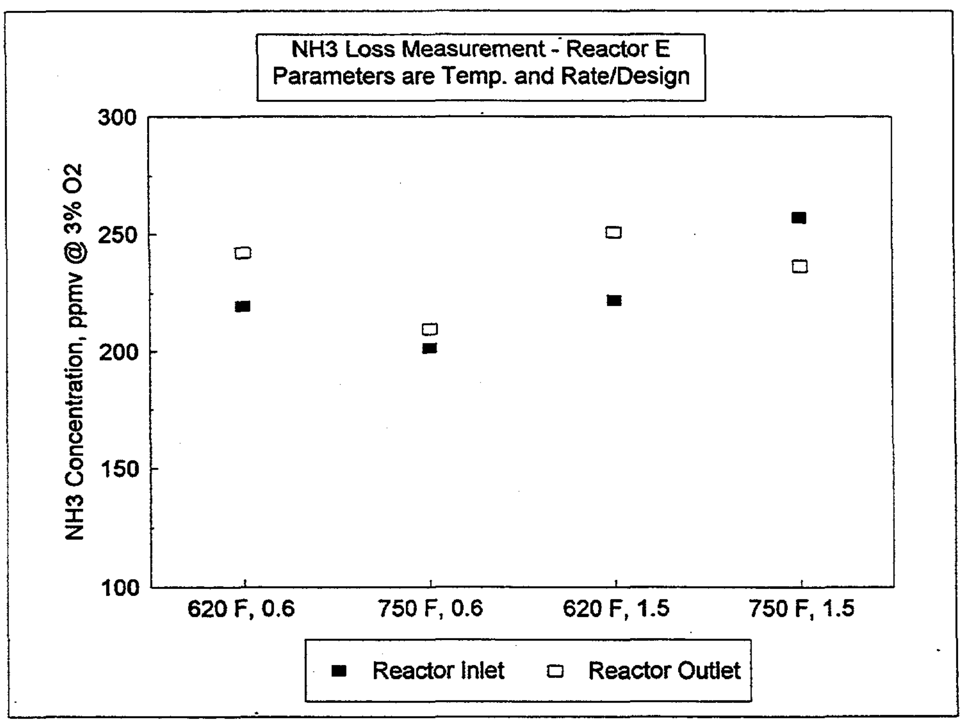

Figure 4-8. Ammonia Loss Across SCR Reactor Without Catalyst: Reactor E

Table 4-2. Mean Ammonia Slip Concentrations During Parametric Tests

Target Reactor Operating Conditions				Mean Ammonia Slip Concentration, dppmv @ 3% O_2							
				Reactor ID							
Test Condition	Temp., °F	Gas Rate/ Design Rate	NH_3/NO_x	A	B	C	D	E	F	G	J
2	620	0.6	0.8	1.6	1.1	1.4	5.4	<0.9	10.9	<1.0	1.1
4	620	0.6	1.0	—[a]	—	—	—	2.4	8.1	—	—
6	620	1.0	0.6	1.8	<0.8	2.5	5.1	<0.8	1.0	<0.9	1.2
7	620	1.0	0.8	3.3	<1.0	6.6	12.2	<1.0	2.3	1.8	2.0
9	620	1.0	1.0	10.4	5.8	38.0	54.8	4.9	31.0	38.7	5.0
12	620	1.5	0.8	9.8	2.4	7.0	36.1	1.4	4.6	1.3	
14	620	1.5	1.0	14.5	17.3	38.2	72.2	33.5	38.1	20.6	15.7
16	700	0.6	0.6	1.0	—	1.5	—	—	—	—	—
19	700	0.6	1.0	2.1	1.8	16.5	—	—	—	—	—
21	700	1.0	0.6	1.6	<1.1	2.3	2.2	<1.1	1.1	0.7	<0.8
22	700	1.0	0.8	3.3	1.6	4.1	4.6	<1.3	13.8	1.7	1.1
24	700	1.0	1.0	1.8	5.4	20.9	25.3	1.5	10.3	23.4	2.9
26	700	1.5	0.6	1.6	1.0	4.8	5.0	0.8	3.2	2.5	1.5
27	700	1.5	0.8	2.7	1.4	8.8	13.1	1.1	5.4	4.4	3.4
29	700	1.5	1.0	4.9	4.9	25.3	38.9	6.7	28.7	21.5	12.3
36	750	1.0	0.6	1.5	0.9	2.5	2.1	<0.9	1.7	1.0	1.6
37	750	1.0	0.8	1.9	0.9	4.9	4.5	<0.8	1.9	2.1	2.8
39	750	1.0	1.0	4.1	2.0	13.3	16.5	<0.8	19.0	15.0	6.8
42	750	1.5	0.8	2.9	0.9	4.4	15.4	<1.2	3.7	2.3	—

[a] Dash indicates that tests were not performed at these conditions.

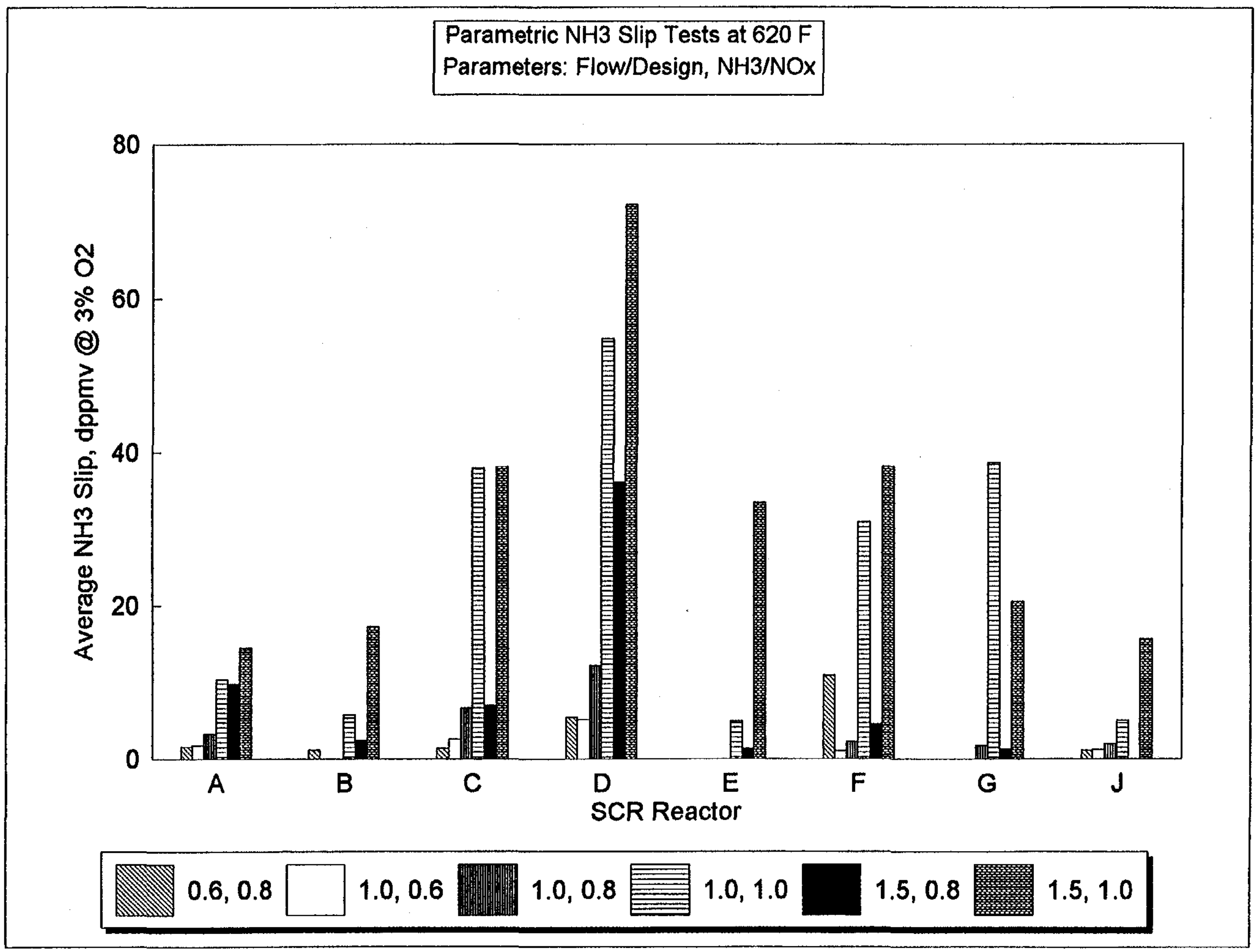

Figure 4-9. Effect of Gas Velocity and NH_3/NO_x Ratio on Ammonia Slip During 620°F Parametric Test Series

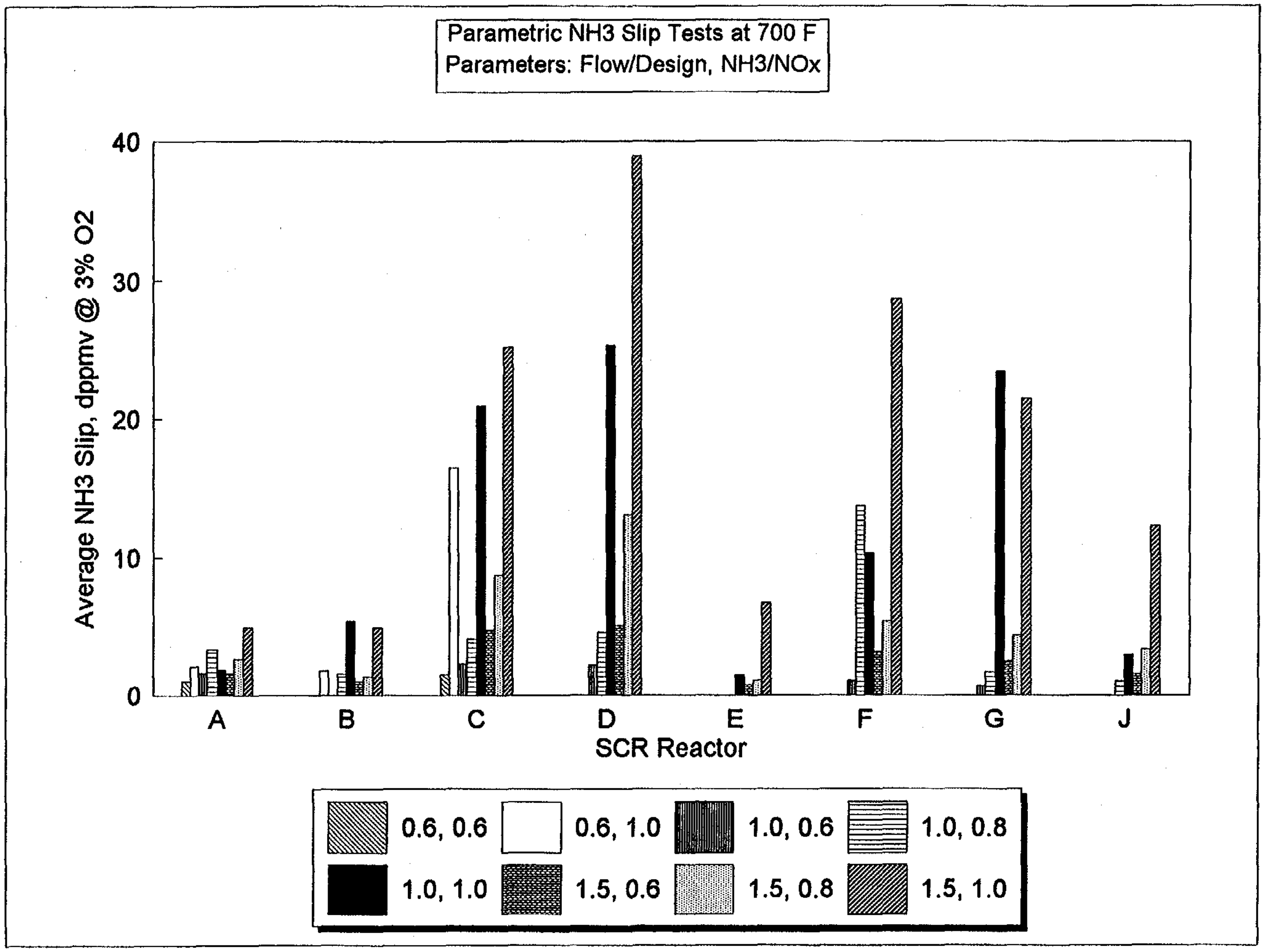

Figure 4-10. Effect of Gas Velocity and NH_3/NO_x Ratio on Ammonia Slip During 700°F Parametric Test Series

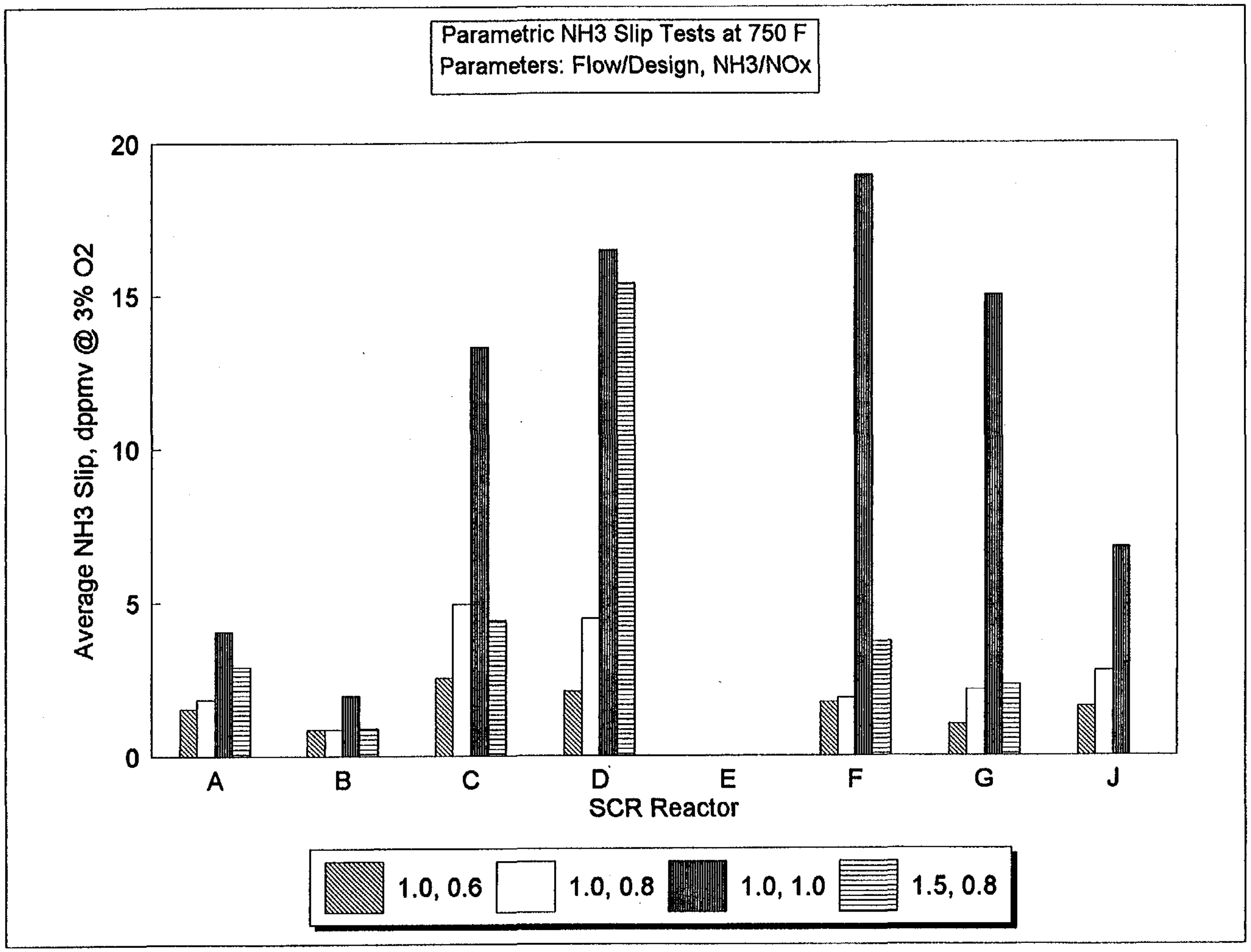

Figure 4-11. Effect of Gas Velocity and NH_3/NO_x Ratio on Ammonia Slip During 750°F Parametric Test Series

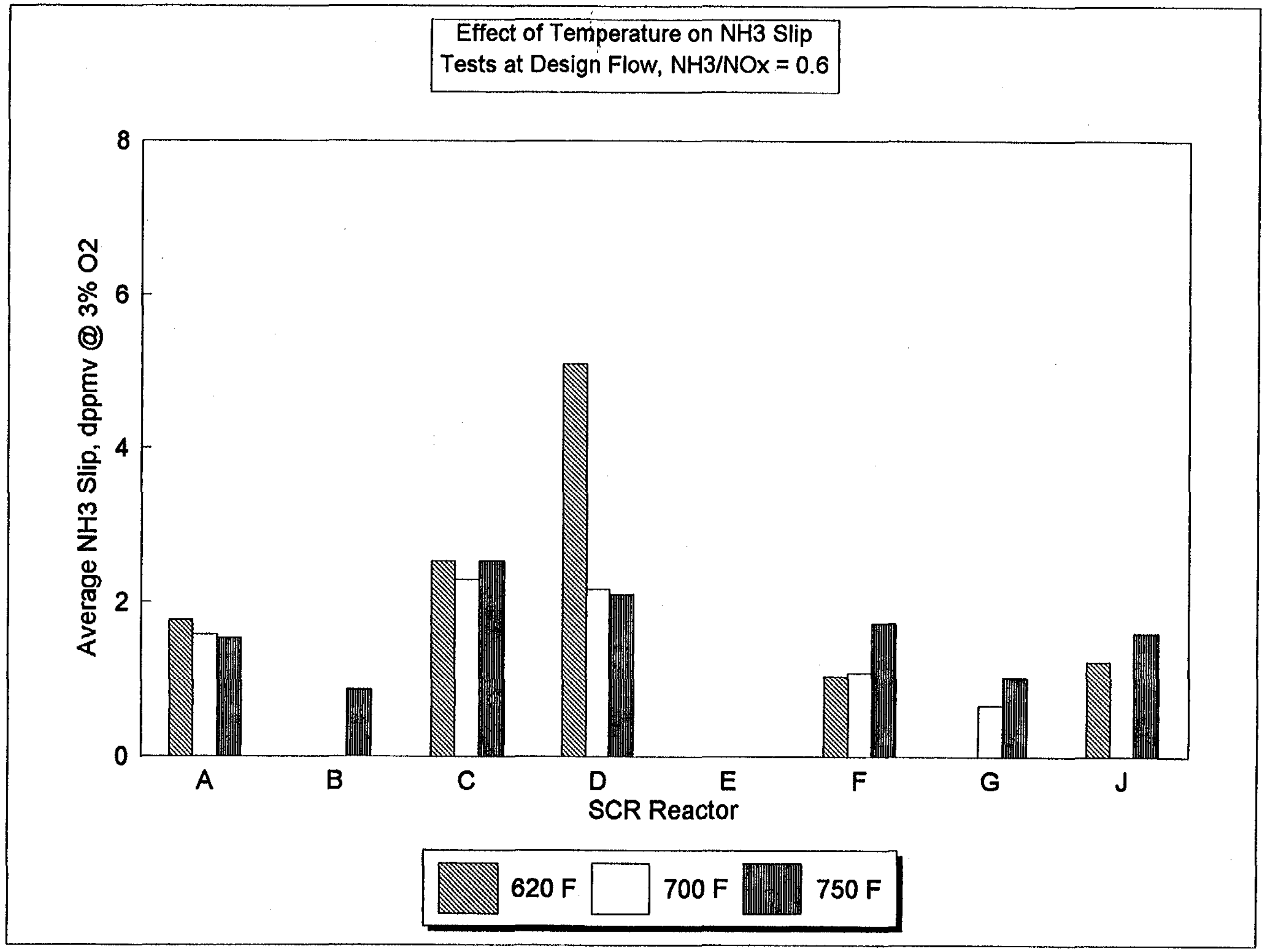

Figure 4-12. Effect of Temperature on Ammonia Slip: Parametric Tests at Design Flow and NH_3/NO_x = 0.6

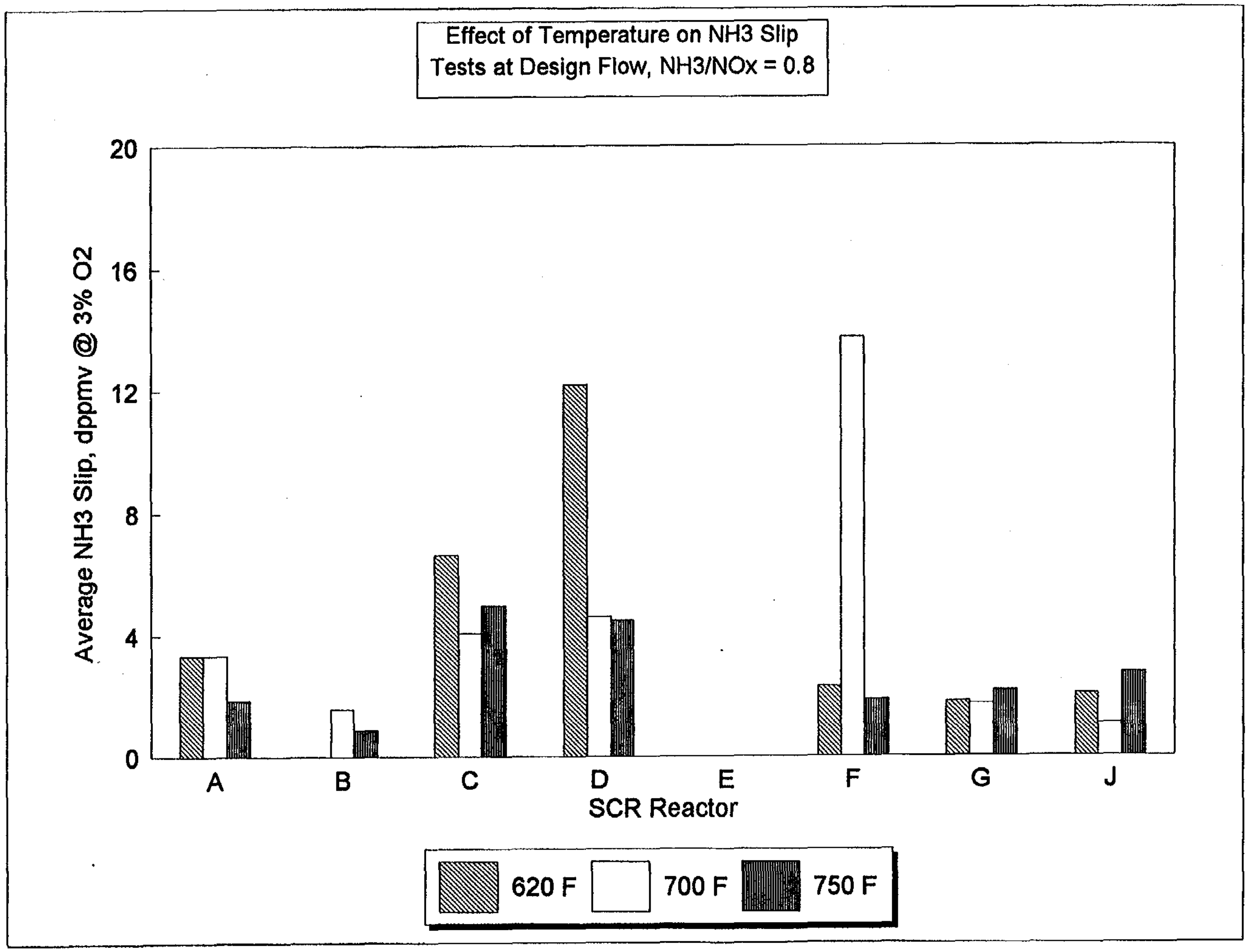

Figure 4-13. Effect of Temperature on Ammonia Slip: Parametric Tests at Design Flow and NH_3/NO_x = 0.8

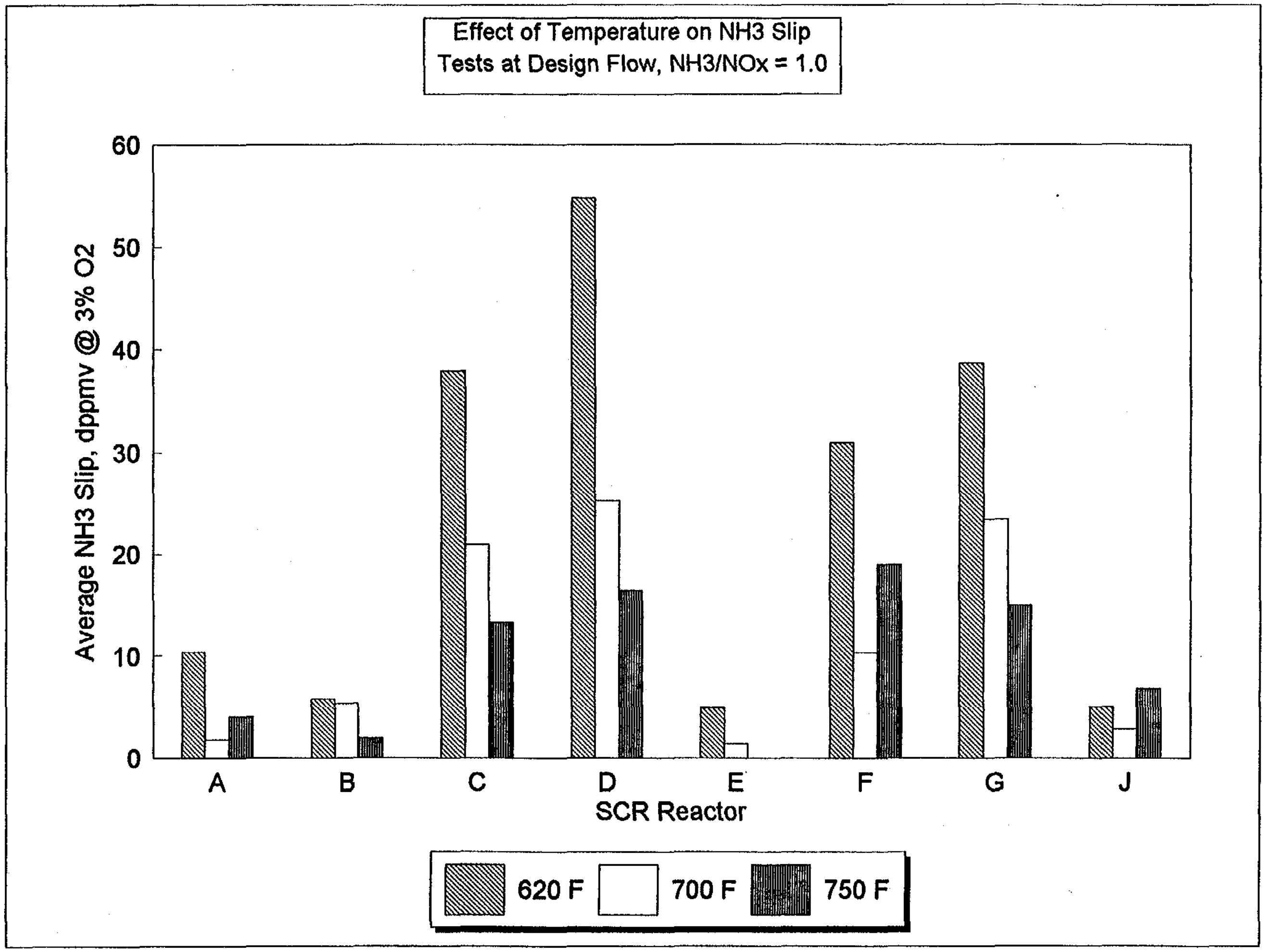

Figure 4-14. Effect of Temperature on Ammonia Slip: Parametric Tests at Design Flow and NH_3/NO_x = 1.0

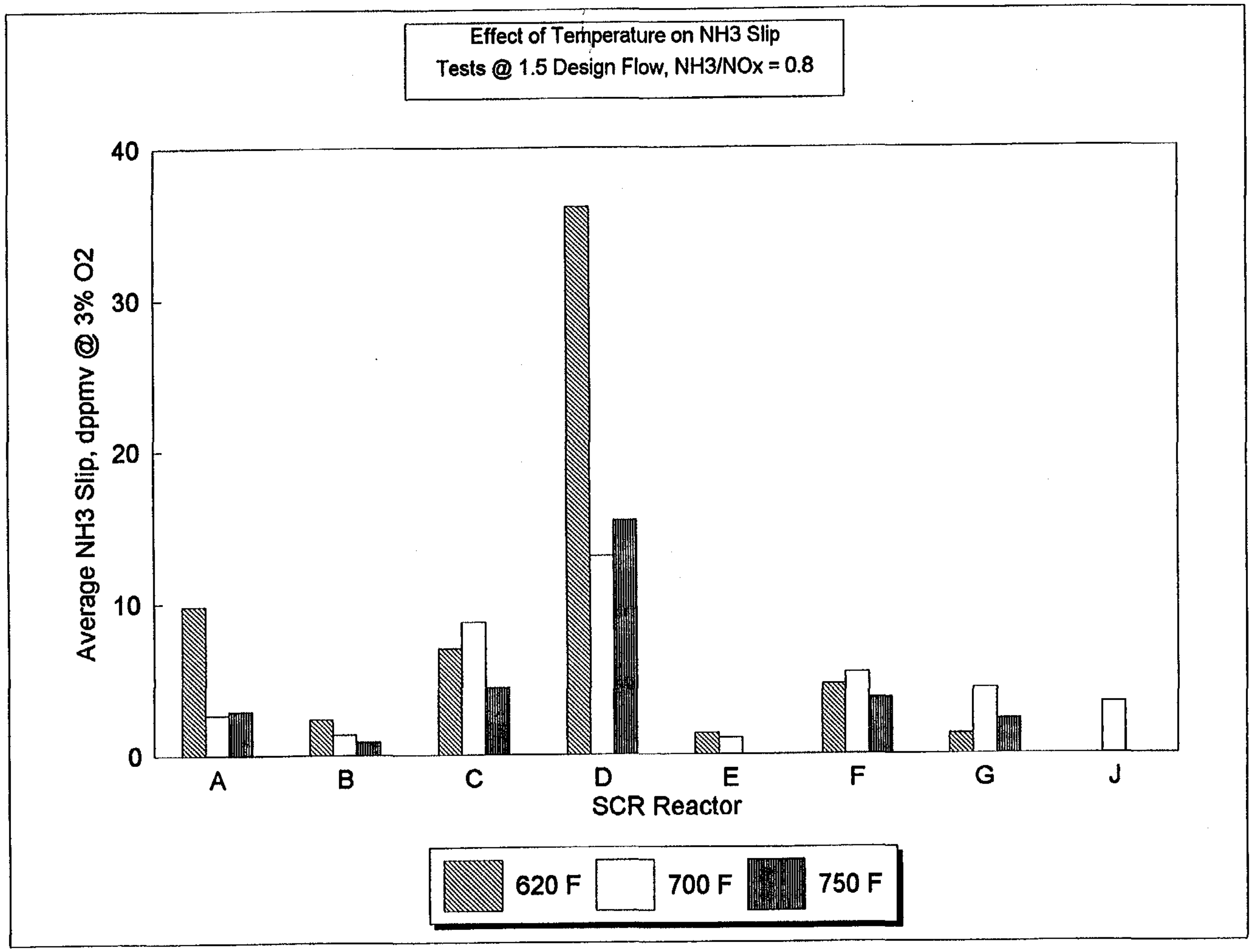

Figure 4-15. Effect of Temperature on Ammonia Slip: Parametric Tests at 1.5 x Design Flow and NH_3/NO_x = 0.8

SO_2 concentrations and coal sulfur content over time is shown in Figure 4-16. In general, the flue gas SO_2 content increased with increasing coal sulfur content, as expected.

The conversion of SO_2 to SO_3 across the SCR reactors was investigated by measuring reactor inlet and outlet concentrations of both species at several sets of reactor operating conditions during preliminary parametric testing, and later during the long-term parametric tests. A summary of the mean conversions at each test condition is provided in Table 4-3; the detailed data can be found in Appendix A, Tables A-6, A-9, A-10, and A-11. As an example, the results of the SO_2 conversion tests for SCR Reactor A are shown in Figure 4-17. In general, the fraction of the flue gas SO_2 converted to SO_3 across a given reactor increased with increasing temperature and increasing residence time (i.e., decreased flue gas flow rate). Figure 4-18 shows how the SO_2 conversion across each reactor changed over time. In most cases, the fraction of SO_2 converted to SO_3 decreased slightly over time as the catalysts aged. Less than 0.5% of the SO_2 was converted to SO_3 in the majority of cases.

4.1.4 Nitrous Oxide (N_2O)

Nitrous oxide concentrations were measured at the inlet and outlet of the SCR reactors during three of the long-term parametric test series at baseline reactor operating conditions (i.e., 700°F, design flow rates, and NH_3/NO_x ratio of 0.8). Care was taken to avoid the formation of N_2O in the sample container following sample collection. Test results are summarized in Table 4-4 and Figure 4-19. Measured concentrations of N_2O at the inlets and outlets of the reactors were all low, ranging from about 1 ppmv to 3 ppmv. Within the precision of the measurements, there did not appear to be a significant change in N_2O concentrations across the reactors.

4.1.5 Hydrogen Chloride (HCl)

Hydrogen chloride concentrations were measured at the reactor inlets and outlets during parametric tests conducted at the baseline reactor operating conditions (i.e., 700°F, design flow rates, and NH_3/NO_x ratio of 0.8). The results are summarized in Table 4-5 and Figures 4-20 and 4-21. The apparent increase in measured HCl concentration across each of the SCR reactors during test sequence 4 (as shown in Figure 4-21) was very probably an artifact of the sampling method used to collect reactor inlet and outlet samples. The sampling protocol used at the reactor inlet did not include particulate catch. It is probable that some of the HCl reacted with ammonia upstream of the SCR reactors to form solid-phase ammonium chloride, which probably attached to the fly ash particles. Then, as the temperature was raised to the equilibrium temperature of the

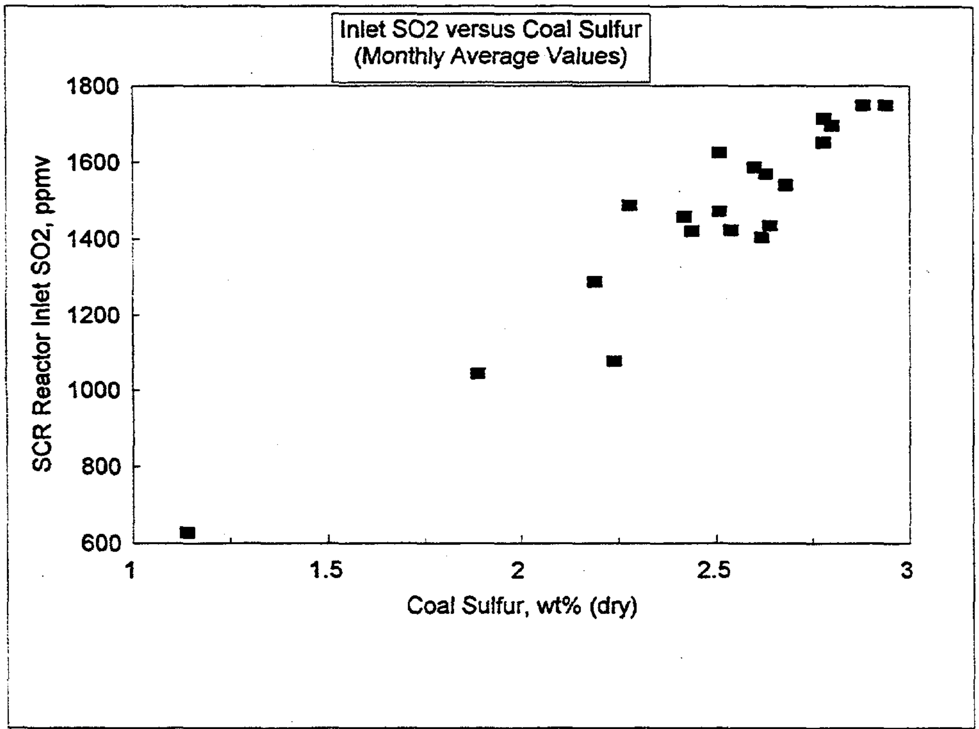

Figure 4-16. Variation of Reactor Inlet SO_2 Concentration with Coal Sulfur Content

Table 4-3. SO_2 Conversion Test Results

Target Reactor Operating Conditions				Mean SO_2 Conversion, % of Inlet SO_2 Converted to SO_3							
Test Condition	Temp., °F	Gas Rate/ Design Rate	NH_3/NO_x	A	B	C	D	E	F	G	J
2	620	0.6	0.8	0.20	0.00	—[a]	—	—	—	—	—
7	620	1.0	0.8	0.07	0.00	—	—	—	—	—	—
12	620	1.5	0.8	0.00	0.12	—	—	—	—	—	—
17	700	0.6	0.8	1.15	0.44	—	—	—	—	—	—
22	700	1.0	0.8	0.61	0.07	0.67	0.29	0.25	0.03	0.09	0.28
27	700	1.5	0.8	0.83	0.21	0.00	0.00	0.34	0.00	0.11	0.29
32	750	0.6	0.8	1.93	0.61	2.64	—	—	—	—	—
37	750	1.0	0.8	1.82	0.45	1.53	0.80	0.59	0.06	0.74	0.60
42	750	1.5	0.8	1.22	0.25	1.99	—	—	—	—	—

[a] Dash indicates that testing was not performed at these conditions.

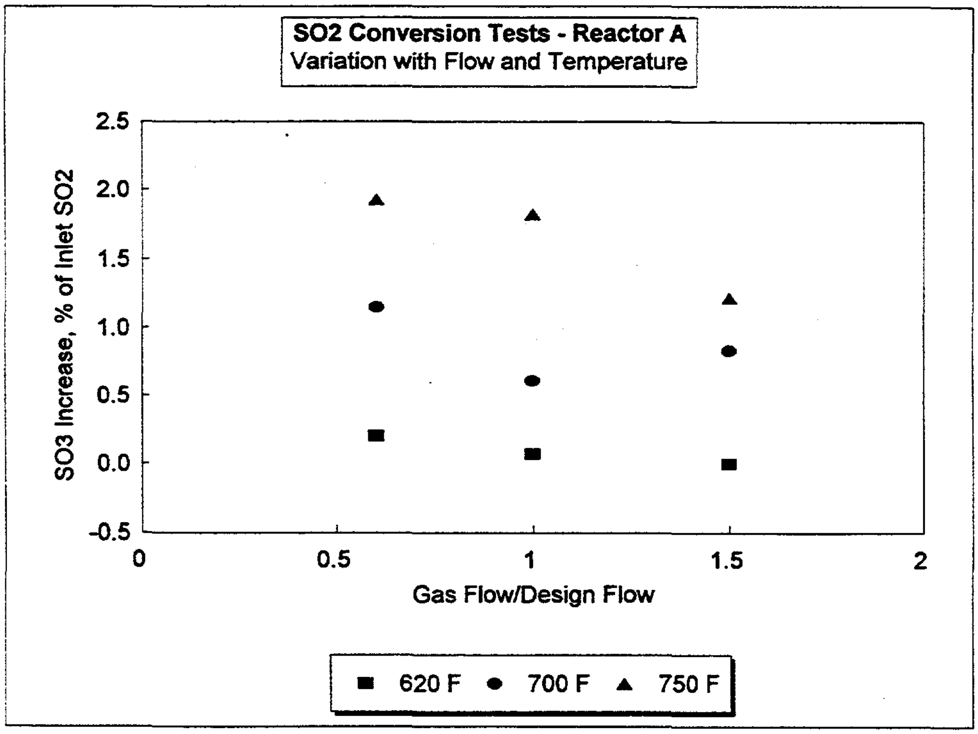

Figure 4-17. Example of Variation in SO_2 Conversion with Flue Gas Flow and Reactor Temperature—Reactor A

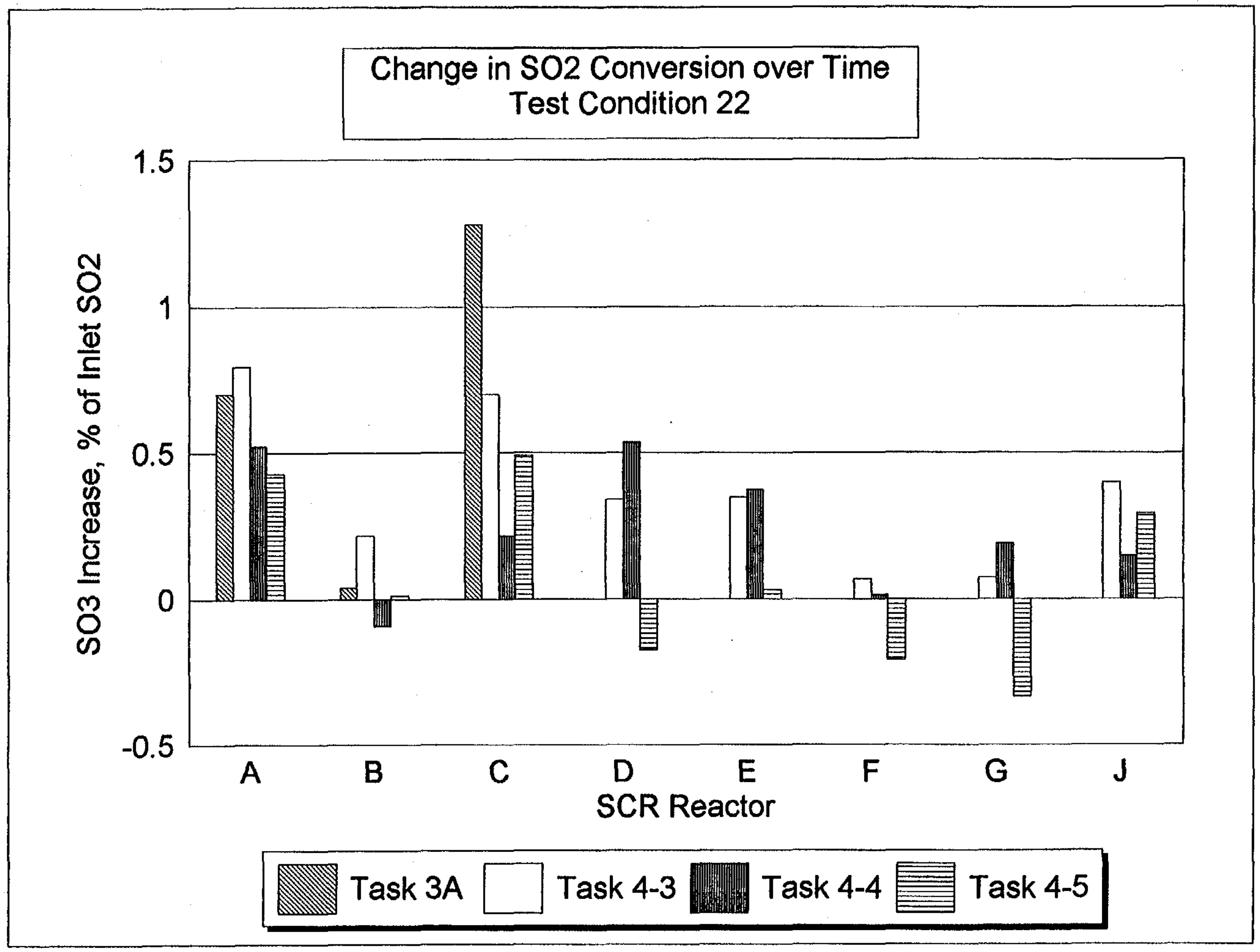

Figure 4-18. Change in SO_2 Conversion Across SCR Reactors with Exposure Time

Table 4-4. Mean Nitrous Oxide Concentration Summary (dry ppmv at 3% O_2)

SCR Reactor	Test Sequence 2		Test Sequence 4		Test Sequence 5	
	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
A	2.4	1.2	1.2	1.3	2.0	1.6
B	2.4	1.0	1.2	1.3	2.0	1.6
C	2.4	1.7	1.2	2.0	2.0	2.5
D	1.8	1.8	1.2	2.0	2.0	2.1
E	1.8	1.8	1.2	1.8	2.0	1.8
F	2.4	1.6	1.2	2.0	2.0	2.2
G	2.4	1.6	1.2	2.3	2.0	1.6
J	—[a]	—	1.2	2.5	2.0	2.9

[a] Dash indicates that tests were not performed at these points.

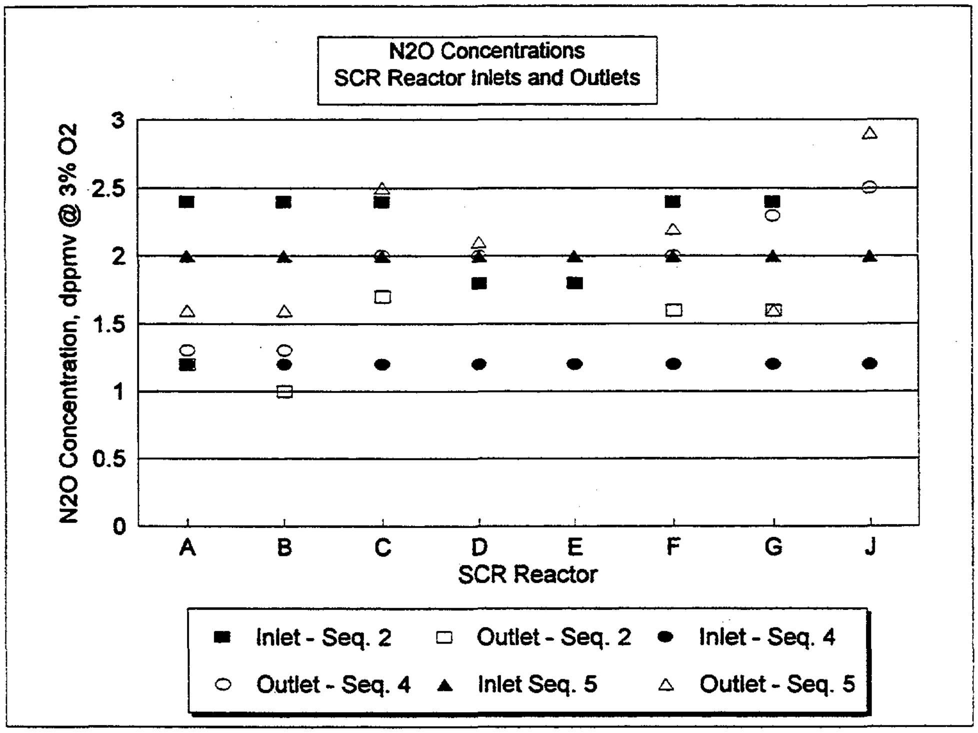

Figure 4-19. Reactor Inlet and Outlet Nitrous Oxide Concentrations

Table 4-5. HCl Concentration Summary

Test Sequence	SCR Reactor	Date	HCl Conc., dppmv @ 3% O_2	
			Inlet	Outlet
1	A	06Aug93	—[a]	178
1	B	16Jul93	—	152
1	C	14Jul93	—	137
1	C	15Jul93	—	143
1	C	19Jul93	—	125
1	D	27Oct93	—	135
1	E	27Oct93	—	211
1	F	27Oct93	—	202
2	A	28Jan94	—	241
2	B	01Feb94	—	158
2	C	28Jan94	—	211
2	D	02Feb94	—	163
2	E	17Mar94	—	196
2	F	16Mar94	—	140
2	G	23Mar94	—	157
3	A	20Sep94	—	233
3	B	19Sep94	—	238
3	C	20Sep94	—	233
3	D	23Sep94	—	232
3	E	23Sep94	—	226
3	F	20Sep94	—	241
3	G	21Sep94	—	225
3	J	21Sep94	—	234
4	A	01Dec94	139	219
4	B	30Nov94	161	222
4	C	28Nov94	195	260
4	D	05Dec94	164	223
4	E	06Dec94	176	233
4	F	07Dec94	174	250
4	G	08Dec94	189	256
4	J	09Dec94	179	244
5	A	03Jun95	132	86

[a]Dash indicates that measurements were not made at these locations.

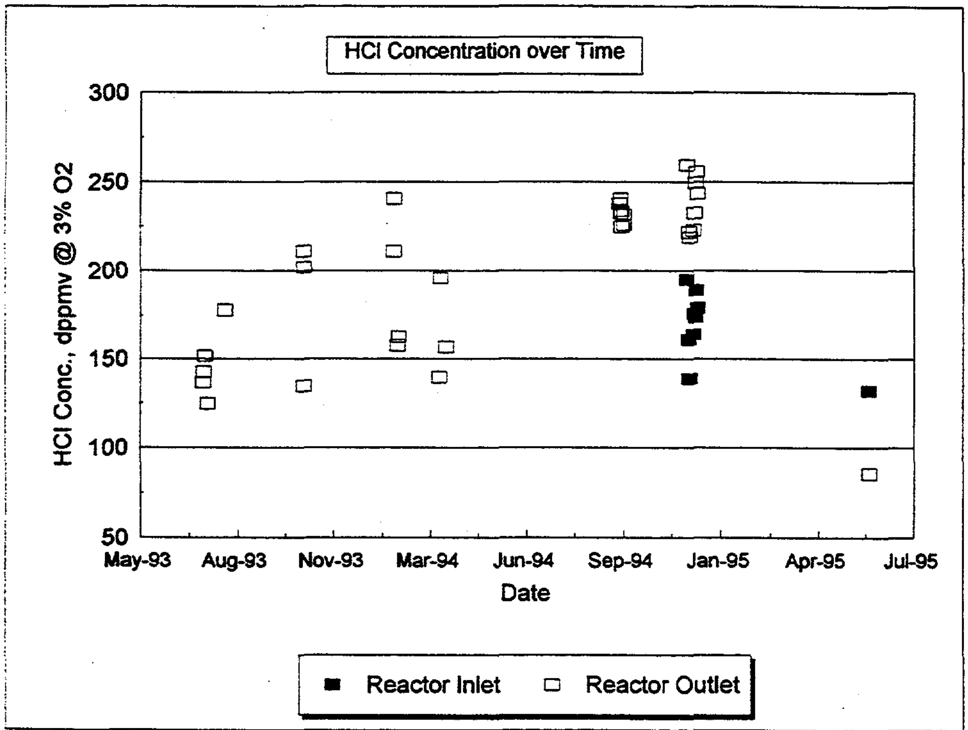

Figure 4-20. Variation in Reactor Outlet HCl Concentrations with Time

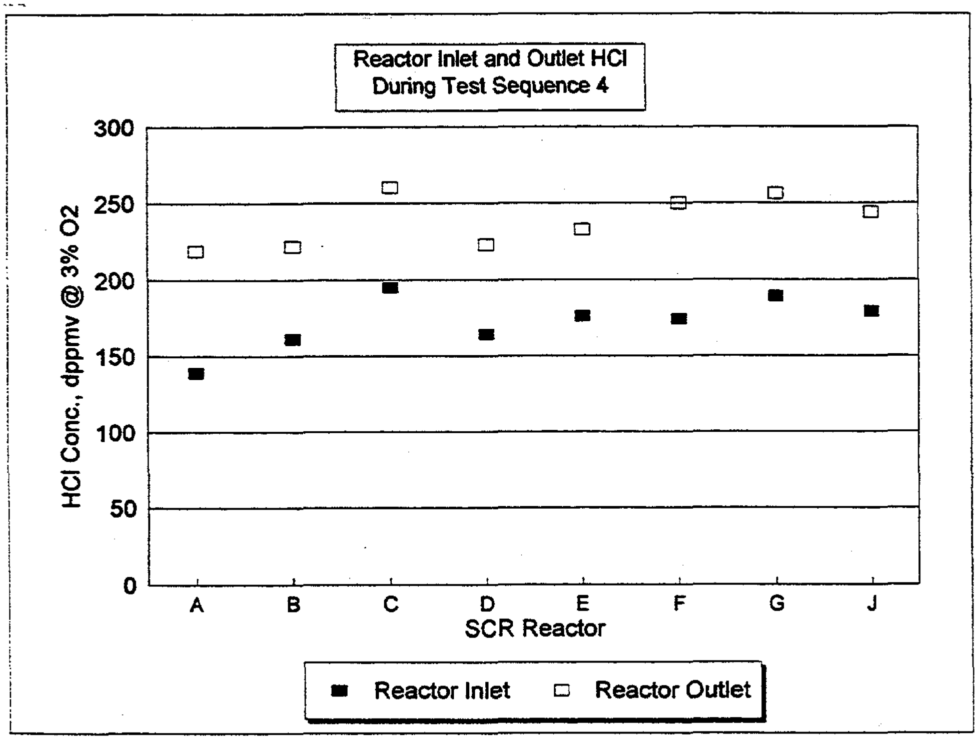

Figure 4-21. Reactor Inlet and Outlet Hydrogen Chloride Concentrations

SCR reactors, the ammonium chloride probably evolved back into its original components (ammonia and HCl), thus resulting in an apparent increase in the HCl concentration.

4.1.6 Particulate Matter

Particulate matter (PM) sampling and analyses were conducted (1) to demonstrate that the concentration (i.e., loading) and particle size of the PM in the flue gas to each SCR reactor were similar to those characteristics in the flue gas flowing to the Unit 5 hot-side ESP; (2) to determine the particulate loading downstream of the three large SCR reactors and around the air preheaters downstream of these reactors; and (3) to characterize the composition of the fly ash at these locations, including ash minerals, trace metals, ammonia, and TCLP analyses.

PM Loading: Low-Dust Flue Gas

The mean particulate matter loading in the low-dust flue gas leaving the hot-side ESP was 0.0043 grains per dry standard cubic foot (gr/dscf), at high boiler load conditions (84 MWe); the corresponding loading measured at the inlet of the low-particulate SCR reactor (Reactor J) was 0.0022 gr/dscf. The difference between these measurements was probably due to differences in sampling methods used at the two locations. The ESP outlet flue gas measurements were conducted using a detailed traverse of the entire outlet duct cross section, while the Reactor J take-off duct samples (reactor inlet samples) represented only a fraction of the total duct cross-sectional area. At low boiler load (43 MWe), the mean particulate loading in the ESP outlet flue gas was 0.0007 gr/dscf; no measurements were made of the Reactor J inlet duct particulate loading at this operating condition because of the extremely low levels expected.

Loading: High-Dust Flue Gas

The first set of particulate matter loading measurements in the high dust flue gas showed that modifications to the design of the flue gas inlet (to the SCR reactors) transition piece were needed to improve the isokinetic flow between the transition piece and the ducting to the five small high-dust reactors (Reactors D, E, F, G, and H). The results of tests conducted after these modifications were completed are summarized in Table 4-6 and Figure 4-22. Because of difficulties in collecting representative samples at the inlet to each of the five small high-dust reactors, the measurements were made downstream of the last catalyst layer in each reactor. Tests were conducted with the Unit 5 boiler operating at two load conditions: high (84 MW) and low (43 MW). The average PM concentration at high boiler load was 3.9 gr/dscf @ 3% O_2. At low boiler load conditions, the average PM concentration for all eight high-dust reactors was 3.5 gr/dscf @ 3% O_2. By comparison, the average PM loadings at the ESP inlet at high and low

Table 4-6. Average SCR Reactor Outlet PM Loadings[a]

SCR Reactor	Low Load	High Load				
	Task 1	Task 1	Task 4[b] Sequence 1	Task 4 Sequence 2	Task 4 Sequence 4	Mean
A	3.60	3.91	—[c]	3.49	3.87	3.75
B	3.41	4.13	4.99	3.78	3.27	4.04
C	3.51	3.84	4.77	3.27	3.42	3.82
D	3.46	3.13	2.89	3.72	4.24	3.49
E	3.88	4.20	3.39	5.25	4.25	4.27
F	3.74	4.38	4.01	7.87[d]	4.34	4.24
G	3.29	3.88	—	—	3.31	3.59
H	3.29	3.75	—	—	—	3.75

[a] Units = grains/dry standard cubic feet.
[b] No tests were conducted during Test 4, Sequence 3.
[c] Dash indicates that no loading tests were performed at these conditions.
[d] Not included in calculation of overall mean.

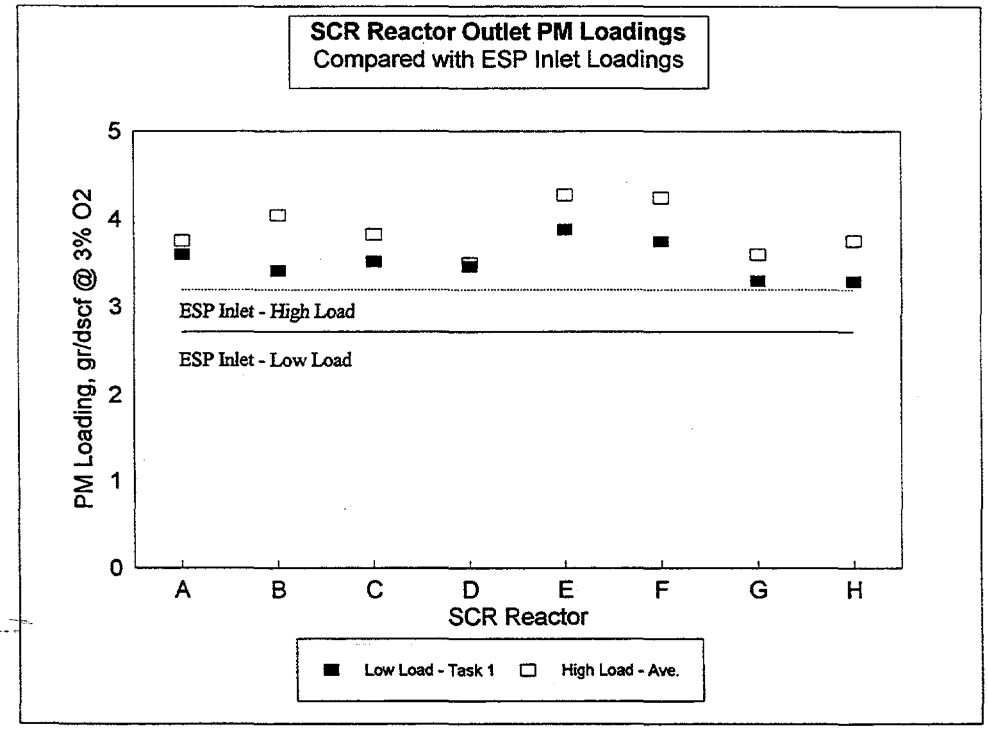

Figure 4-22. SCR Reactor Outlet PM Loadings Compared with ESP Inlet Loadings

boiler load conditions were 3.2 and 2.7 gr/dscf, respectively. Subsequent measurements of particulate loadings in the economizer bypass duct at low load conditions showed that the particulate loading measured at the ESP inlet may have been low. The average mass loading in the economizer bypass duct, 3.60 gr/dscf, was comparable to that found in the reactor outlets at similar boiler load conditions.

The average particulate loading at various locations downstream of the three large high-dust reactors are shown in Figure 4-23. As expected, PM loadings at the SCR reactors outlets and air preheater inlets were comparable, while lower loadings were measured downstream of the preheaters, indicative of some particulate deposition in the air preheaters.

Particle Size Distribution

Figures 4-24 and 4-25 present the differential particle size distributions for the fly ash downstream of the third catalyst level for the high-dust reactors at high and low boiler loads, respectively. For comparison purposes, Figures 4-26 and 4-27 show the average distributions for all eight high-dust reactors compared with the size distribution of the particulate collected at the main ESP inlet at the two boiler loads. The solid lines represent a range of one standard deviation about the mean of particle size distribution in the eight reactors. For both high- and low-load conditions, the particle size distribution at the main inlet to the high-dust reactors agreed very well with the average size distribution measured at the outlet of the eight high-dust SCR reactors.

Fly Ash Composition

Table 4-7 summarizes the results of the ash minerals analyses that were conducted on fly ash samples collected at various locations during the SCR demonstration project. The data show that the compositions of the fly ash entering and leaving the three large high-dust reactors and the air preheaters were very similar to the composition of the coal ash. The trace metals concentrations in the fly ash samples are shown in Table 4-8. Considerably more variability can be seen in these measurements compared with the major ash minerals. This is consistent with the inherent variability of trace element levels in coal.

Ammonia on Particulates

Southern Research Institute conducted a laboratory study to evaluate the effects of SCR ammonia levels on ammonia volatilization, ammonia extraction, and metals extractability from fly ash (9). Samples of pre-SCR reactor (ammonia-free) and post-SCR reactor (ammonia-exposed) fly ash were collected from SCR Reactors B and C. The associated EMP monitoring

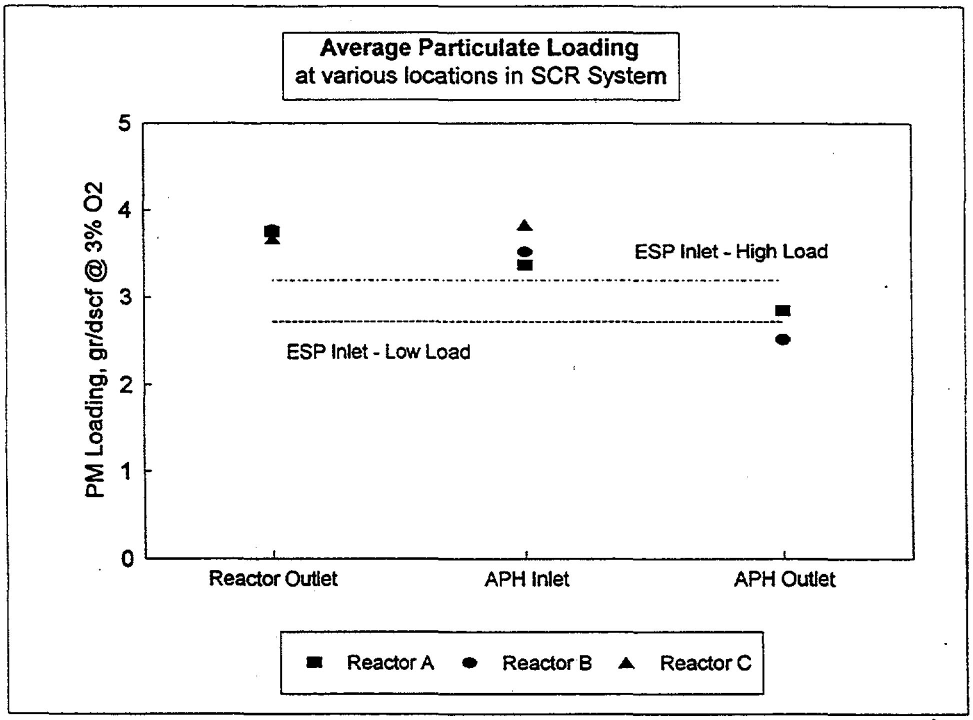

Figure 4-23. Average Particulate Loading at Various Locations in the SCR System

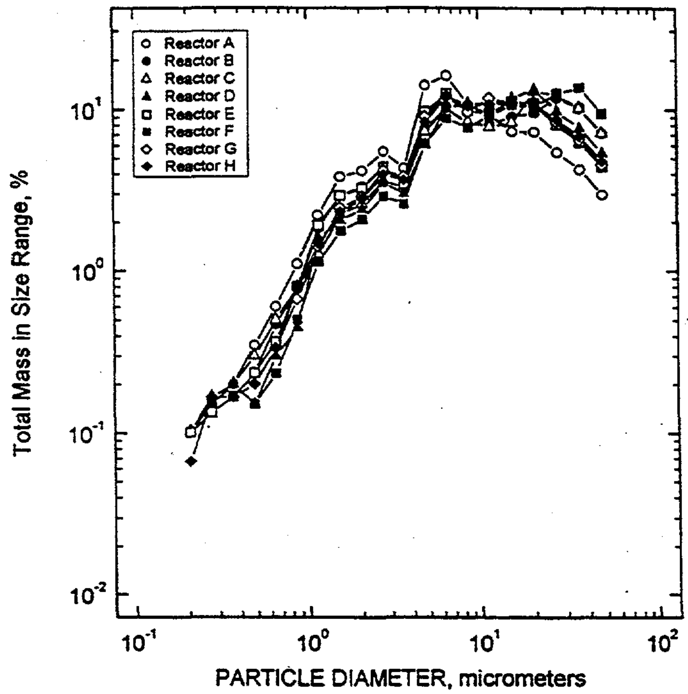

Figure 4-24. Differential Particle Size Distribution for Fly Ash Collected Downstream of the Third Reactor Level (High-Dust Reactors) During High-Load Tests

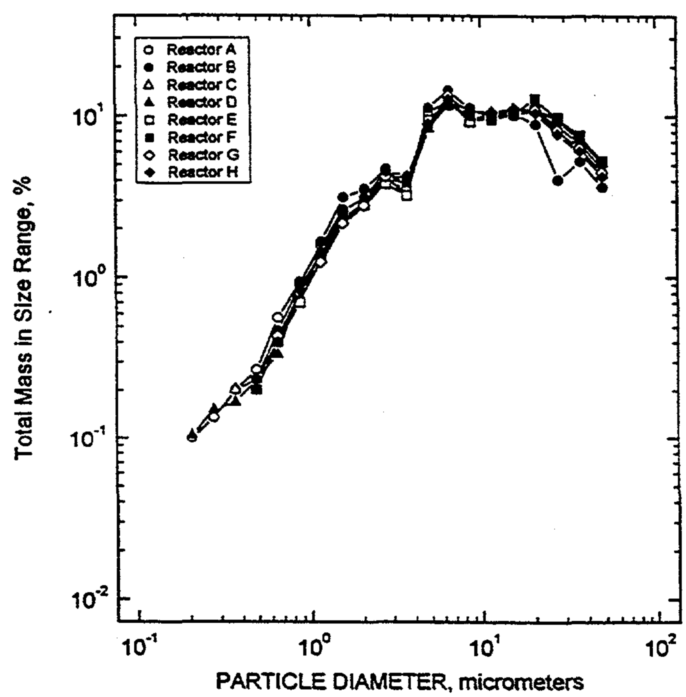

Figure 4-25. Differential Particle Size Distribution for Fly Ash Collected Downstream of the Third Reactor Level (High-Dust Reactors) During Low-Load Tests

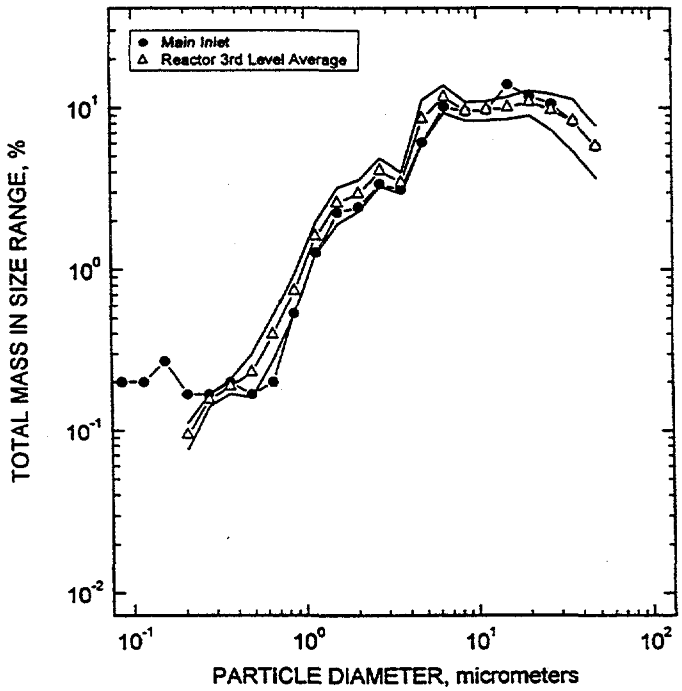

Figure 4-26. Comparison of Differential Particle Size Distributions: Hot-Side ESP Inlet and Average of High-Dust Reactors at High Load

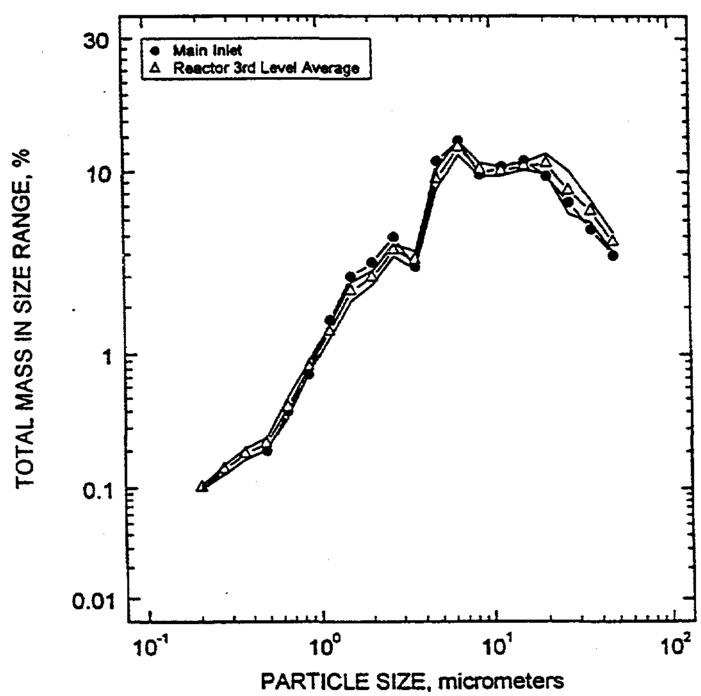

Figure 4-27. Comparison of Differential Particle Size Distributions: Hot-Side ESP Inlet and Average of High-Dust Reactors at Low Load

Table 4-7. Ash Minerals Analyses Summary[a]

Species	As-Fired Coal		ESP Inlet		Reactor A Outlet		Reactor B Outlet	
	10Feb93	11Feb93	9Feb93	10Feb93	25Apr94	8Nov94	02May94	9Nov94
SiO_2	44.3	47.4	48.9	48.4	48.0	47.59	49.3	47.58
Al_2O_3	22.6	22.5	22.7	22.7	22.2	23.73	22.3	24.77
TiO_2	0.83	0.83	1.0	1.0	1.1	1.15	1.1	1.2
Fe_2O_3	19.9	20.6	17.8	18.1	18.7	16.81	18.5	16.82
CaO	4.6	2.8	4.6	4.0	3.5	2.93	2.9	2.54
MgO	0.91	0.78	0.97	0.97	0.98	0.91	1.0	1.06
K_2O	2.3	2.0	2.8	2.5	2.4	2.76	2.4	2.92
Na_2O	0.8	0.66	0.79	0.87	0.97	0.94	1.2	0.98
Others[b]	4.2	2.68	1.19	1.38	2.15	3.18	1.3	2.13

Species	Reactor C Outlet	APH A Outlet		APH B Outlet	
	26Apr94	25Apr94	8Nov94	2May94	9Nov94
SiO_2	49.0	47.4	48.58	49.3	48.36
Al_2O_3	21.9	22.0	24.03	21.7	25.04
TiO_2	0.91	1.1	1.15	0.91	1.24
Fe_2O_3	18.5	20.3	16.61	18.2	15.18
CaO	3.3	3.7	2.98	2.9	2.51
MgO	1.0	0.97	0.93	0.97	0.93
K_2O	2.5	2.2	2.81	2.5	2.96
Na_2O	0.91	0.91	0.96	1.1	1.04
Others[b]	1.98	1.2	1.95	2.42	2.74

[a] Units: % by weight.

[b] Others include SO_2, P_2O_5, Li_2O, SrO, BaO, MnO, and undetermined.

APH = Air preheater.

Table 4-8. Trace Metals Concentrations in Ash Samples[a]

Element	ESP Inlet		ESP Outlet		Reactor A Inlet		APH A Inlet	APH A Outlet	APH B Inlet	APH B Outlet
	9Feb93 High Load	11Feb93 Low Load	9Feb93 High Load	11Feb93 Low Load	6Mar93 High Load	6Mar93 Low Load	8Nov94	8Nov94	9Nov94	9Nov94
Antimony	9	2.9	<180.0	<3.6	6.1	8.3	15	12	12	17.3
Arsenic	139	69.7	110	97.9	51.3	47.2	145	146	146	171
Barium	298	377	339	563	302	259	305	357	455	431
Beryllium	11.3	14.5	<35.0	21	9.6	10.3	17.6	17.3	17.7	18.2
Cadmium	5.9	10.3	39.1	20	4.6	7.2	4.3	<4.0	<4.0	<4.0
Cesium	85.5	74.6	<3500	<80.0	72.9	69.9	<33	<32	<32	<31
Chromium	124	148	241	152	132	124	148	151	151	168
Cobalt	23	30.6	<70.0	30.7	27.4	22.8	50.6	50.1	53.8	54.1
Copper	71.6	86.4	215	93.2	66.2	65.4	125	125	144	148
Lead	221	286	426	404	227	239	298	227	277	319
Manganese	152	172	226	174	225	169	173	168	158	160
Mercury	0.35	0.13	<7.0	0.21	0.12	0.18	0.019	0.63	<0.010	1.29
Molybdenum	72.9	77	880	85.7	82.6	74.6	26.3	25.2	25.3	27.8
Nickel	86.5	104	<180	106	100	89.5	156	157	167	179
Rubidium	134	126	<1800	125	132	123	93.2	117	155	142
Selenium	99.3	8.02	514	13.7	1.37	7.1	<0.56	3.7	<0.54	6.7
Strontium	186	237	228	252	188	175	472	546	766	736
Tin	26.8	31.1	<180	22.7	21.5	20	78.2	83.9	93.1	75.8
Vanadium	683	458	577	428	467	531	348	348	368	380
Zinc	311	647	3320	1118	436	353	247	252	227	241

[a] Concentration units: μg/g (ppmw).

parameters are summarized in Tables 4-9 and 4-10 and Figures 4-28 through 4-30. Rather than analyzing for solid-phase ammonia compounds, SRI subjected samples of fly ash to extraction using buffered solutions.

As shown in Table 4-9, the ammonia concentration on the reactor inlet fly ash was below detectable levels, as expected. Ammonia was present, however, in the SCR reactor outlet fly ash samples. Table 4-9 and Figure 4-28 show that the amount of ammonia on the post-SCR reactor fly ash increased as the NH_3/NO_x ratio increased.

Table 4-10 and Figures 4-29 and 4-30 show that the ammonia concentration was much higher in the smaller particle sizes of fly ash, but most of the total ammonia was found to reside with the large particles simply because these comprised the vast majority of the fly ash mass.

Toxicity Characteristic Leaching Procedure (TCLP) Applied to Fly Ash Testing

Composite samples of the SCR inlet flue gas fly ash (collected from the host unit's hot-side ESP hopper) and the SCR reactor outlet gas fly ash (collected as grab samples from the cyclone ash hoppers following each of the high dust SCR reactors) were leached and analyzed for the suite of toxic metals found in the U.S. EPA's TCLP Method, as described in RCRA Subpart C Hazardous Waste Determination regulations. Composite samples were prepared from the individual reactor ash samples. Table 4-11 indicates the reactors from which each set of composite samples was prepared. As shown in Table 4-11, the metals concentrations in the TCLP leachate from all of the samples were much lower than the RCRA limits. Most of the metals were not present above method detection limits; very low concentrations of barium, cadmium, and chromium were measured in some of the samples. Based on these results, the sampled solids would not be considered hazardous wastes under the RCRA Toxicity Characteristic, with respect to toxic metals.

4.2 Long-Term Monitoring Results

Long-term monitoring was conducted using continuous on-line monitors for the following parameters and streams: NO_x and O_2 in the SCR reactor inlet and outlet gas streams and SO_2 and CO in the SCR reactor inlet gas. Oxygen monitoring was performed to allow normalization of the pollutant concentrations.

Table 4-9. Ammonia Concentrations in Flue Gas Particulates

SCR Reactor Target Operating Conditions			Average NH_3 Concentration, $\mu g/g$		
Temp., °F	Flow/Design	NH_3/NO_x	Reactor Inlet (Isokinetic)	APH Outlet (Isokinetic)	APH Ash Hopper
700	1.0	0.6	<6	86	49
700	1.0	0.8	<6	199	244
700	1.0	1.0	<6	812	351

Table 4-10. Size Dependency of Air Preheater Outlet Particulate Ammonia Concentration

Cyclone Stage	Average Aerodynamic D_{50}, μm	Average Particle Mass, g	Average NH_3 Conc., $\mu g/g$
1	7.710	5.130	24
2	4.335	0.644	102
3	2.366	0.202	194
4	1.638	0.085	412
5	0.688	0.0079	734

Note: Target operating conditions: Temperature = 700 °F; Flow/Design = 1.0; NH_3/NO_x ratio = 0.8

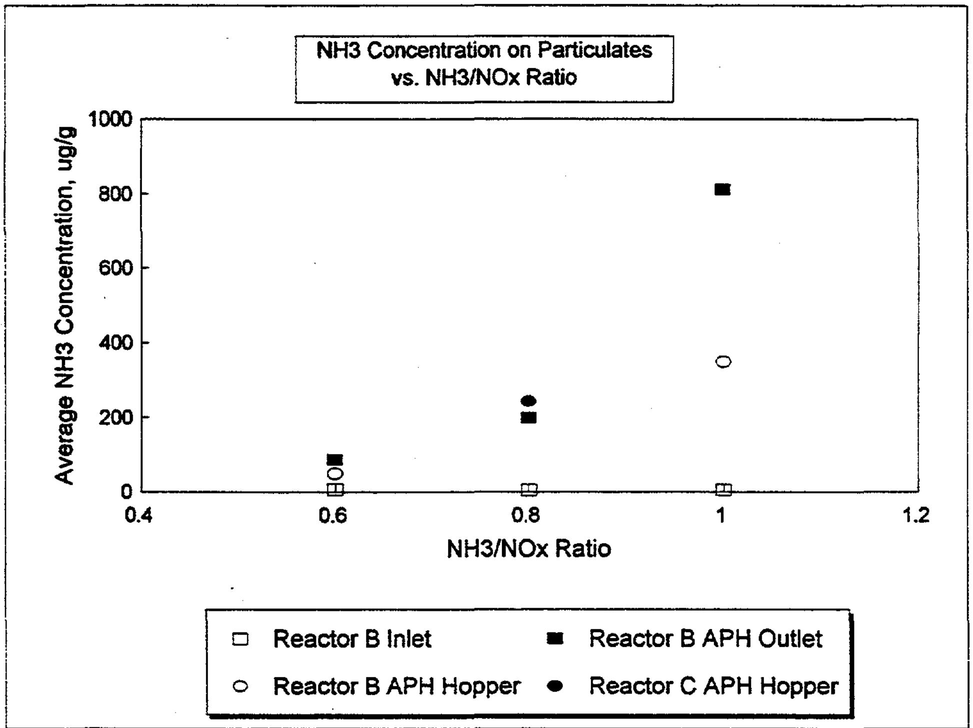

Figure 4-28. Variation in Ammonia Concentration on Flue Gas Particulate Matter with NH_3-to-NO_x Ratio

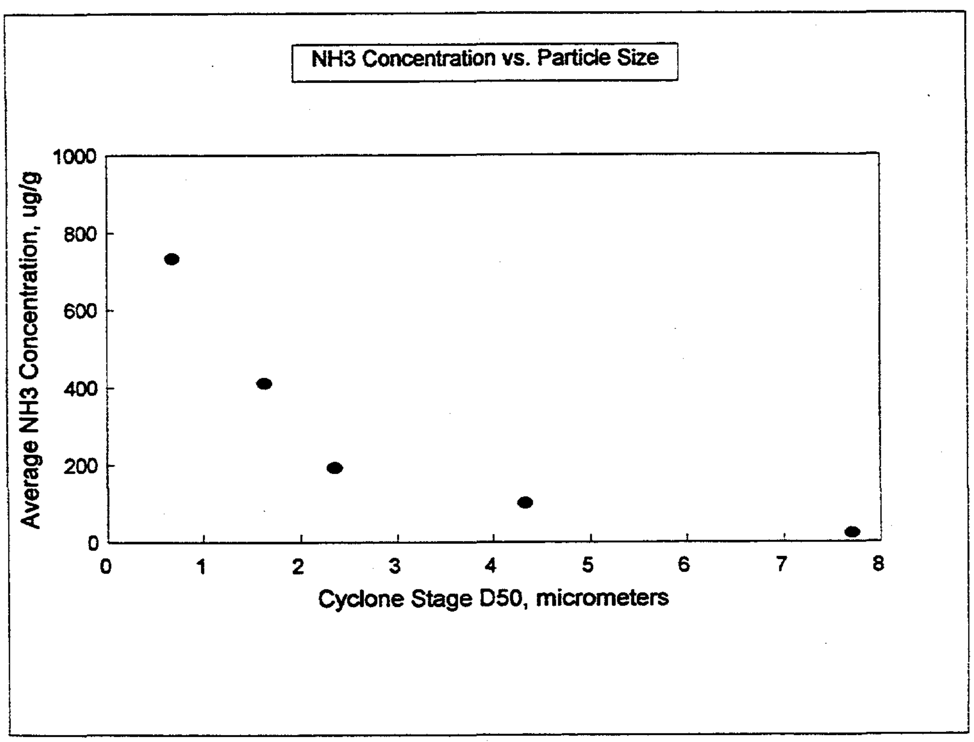

Figure 4-29. Variation in Ammonia Concentration on Flue Gas Particulate Matter with Particle Size

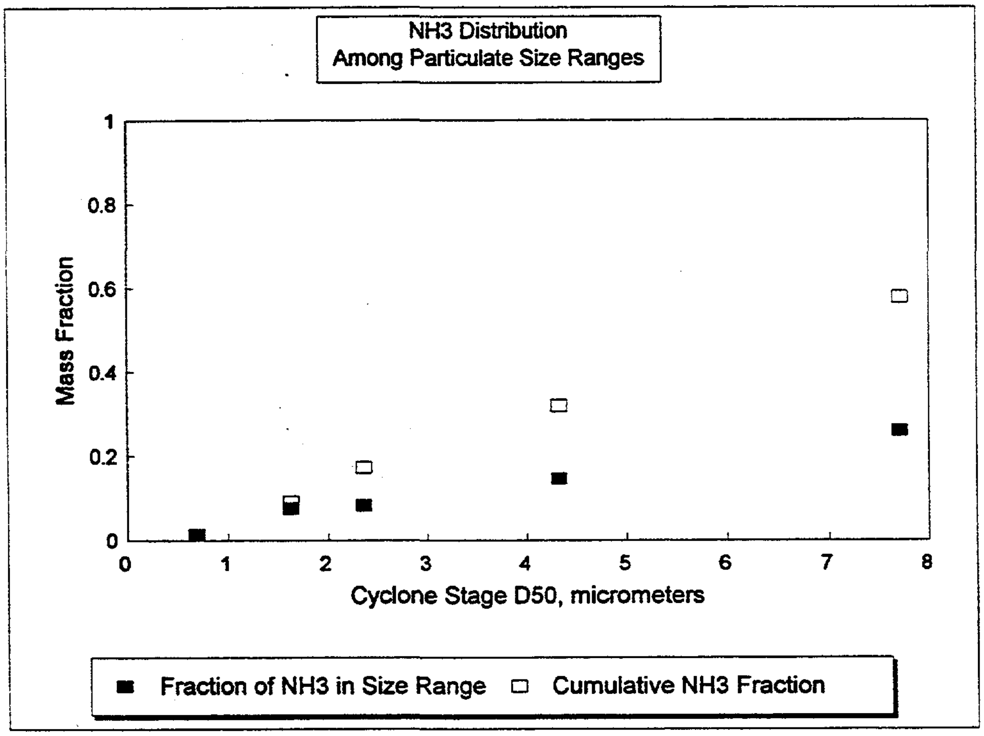

Figure 4-30. Mass Fraction of Ammonia on Flue Gas Particulate Matter Versus Particle Size

Table 4-11. Results of TCLP Metals Analyses: SCR Reactor Solids

Date	Sample Description	TCLP Leachate Analysis, mg/L							
		Ag	As	Ba	Cd	Cr	Hg	Pb	Se
21Jun93	SCR Inlet	<0.5	<0.5	<10	<0.1	<0.5	<0.002	<0.5	<0.1
	SCR Reactor Outlet (A, B, C Composite)	<0.5	<0.5	<10	<0.1	<0.5	<0.002	<0.5	<0.1
28Jun93	SCR Reactor Outlet (A, B, C, D, E, F, G, H Composite)	<0.5	<0.5	<10	<0.1	<0.5	<0.002	<0.5	<1
25Aug94	SCR Inlet	<0.01	<0.05	0.30	0.024	0.04	<0.002	0.05	<0.1
	SCR Reactor Outlet (A, B, C Composite)	<0.01	<0.05	0.33	0.02	0.08	<0.002	0.05	<0.1
	SCR Reactor Outlet (D, E, F, G Composite)	<0.01	<0.05	0.29	0.015	0.04	<0.002	0.05	<0.1
12Jul95	SCR Inlet	<0.01	<0.05	0.24	0.024	0.01	<0.002	<0.05	<0.1
	SCR Reactor Outlet (A, B, C Composite)	<0.01	<0.05	0.24	<0.005	<0.01	<0.002	<0.05	<0.1
	SCR Reactor Outlet (D, E, F Composite)	<0.01	<0.05	0.24	<0.005	<0.01	<0.002	<0.05	<0.1
	SCR Reactor Outlet (G, H Composite)	<0.01	<0.05	0.23	<0.005	<0.01	<0.002	<0.05	<0.1
	RCRA Limits	5.0	5.0	100.0	1.0	5.0	0.2	5.0	1.0

4.2.1 Nitrogen Oxides (NO_x)

Quarterly average flue gas flow rate, NH_3/NO_x ratio, NO_x concentration data for the inlet flue gas and the outlet of each SCR reactor, and NO_x reduction efficiencies are provided in Table 4-12. The values shown represent averages over all operating periods in each quarter, including periods when parametric tests were conducted. The interpretation of these results is not within the scope of the EMP, but is provided in the final SCR demonstration project report (1).

4.2.2 Carbon Monoxide (CO)

The monthly average carbon monoxide concentrations in the SCR reactor inlet gas are plotted versus time in Figure 4-31. With the exception of September and October 1993, the monthly average flue gas CO concentration was relatively consistent at 14-18 ppmv.

4.2.3 Sulfur Dioxide (SO_2)

The monthly sulfur dioxide concentrations in the SCR reactor inlet flue gas are plotted versus time in Figure 4-32. The monthly average SO_2 concentration varied from about 600 to 1800 ppmv. As shown previously, the variability in flue gas SO_2 concentration was due to changes in the coal sulfur content.

Table 4-12. Long-Term SCR Reactor Inlet and Outlet NO_x Concentrations and Reductions Across SCR Reactors

Period	Reactor	Flow Rate scfm	NH_3/NO_x Ratio	Inlet NO_x ppmv	Outlet NO_x ppmv	NO_x Red'n %
Oct-Dec 93	A	4,991	0.77	373	35	88
	B	4,969	0.77	364	33	90
	C	4,945	0.77	359	65	80
	D	392	0.79	340	45	84
	E	393	0.77	358	38	86
	F	378	0.78	353	45	85
	G	—	—	—	—	—
	J	—	—	—	—	—
Jan-Mar 94	A	5,000	0.76	348	71	76
	B	5,070	0.77	344	71	76
	C	5,101	0.77	348	75	75
	D	399	0.77	345	68	73
	E	391	0.75	343	76	73
	F	398	0.76	346	81	71
	G	—	—	—	—	—
	J	—	—	—	—	—
Apr-Jun 94	A	4,992	0.78	347	66	78
	B	4,963	0.77	359	64	81
	C	5,000	0.78	354	59	81
	D	404	0.78	345	78	77
	E	402	0.78	331	52	82
	F	402	0.76	354	56	78
	G	399	0.8	345	51	80
	J	—	—	—	—	—
Jul-Sep 94	A	4,974	0.78	376	82	77
	B	5,050	0.78	370	63	81
	C	5,090	0.78	368	46	86
	D	401	0.80	360	22	92
	E	406	0.80	359	42	86
	F	401	0.76	366	35	86
	G	401	0.79	359	47	84
	J	398	0.76	386	106	71
Oct-Dec 94	A	4,945	0.79	379	49	86
	B	4,987	0.79	377	48	85
	C	4,946	0.79	388	50	85
	D	400	0.79	383	34	89
	E	400	0.79	386	41	88
	F	401	0.79	382	46	86
	G	402	0.79	391	44	85
	J	404	0.76	398	69	79
Jan-Mar 95	A	4,974	0.79	404	48	88
	B	4,954	0.79	399	32	89
	C	4,967	0.79	410	32	89
	D	404	0.80	423	38	89
	E	400	0.79	413	77	80
	F	400	0.78	404	43	88
	G	400	0.79	420	66	81
	J	399	0.75	422	26	88
Apr-Jul 95	A	5,540	0.76	340	61	80
	B	5,128	0.80	338	51	83
	C	5,233	0.71	345	42	85
	D	359	0.79	336	64	78
	E	431	0.66	338	109	62
	F	391	0.66	334	69	75
	G	462	0.58	323	111	46
	J	395	0.61	333	87	60

Notes:
(1) Continuous monitoring data not available prior to the fourth quarter of 1993
(2) Data not available for Reactor G until second quarter 1994 due to catalyst damage and change out.
(3) Data not available for Reactor J until third quarter 1994 due to withdrawal of catalyst supplier participant and subsequent supplier replacement change out.
(4) All data corrected for oxygen variations.

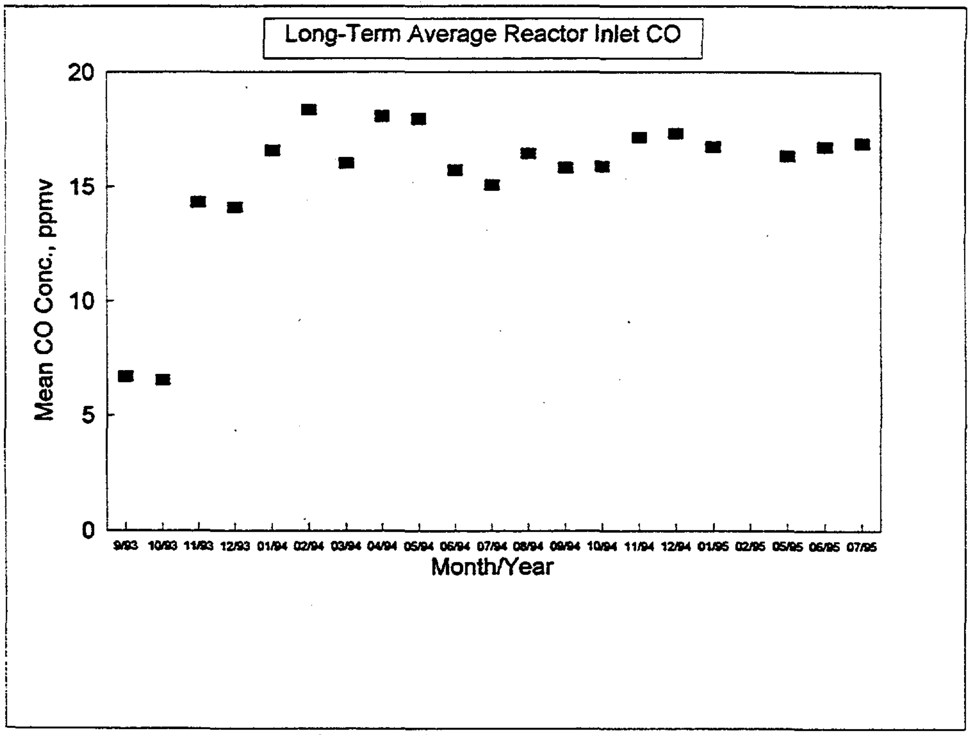

Figure 4-31. Monthly Average Reactor Inlet CO Concentration During the SCR Demonstration Project

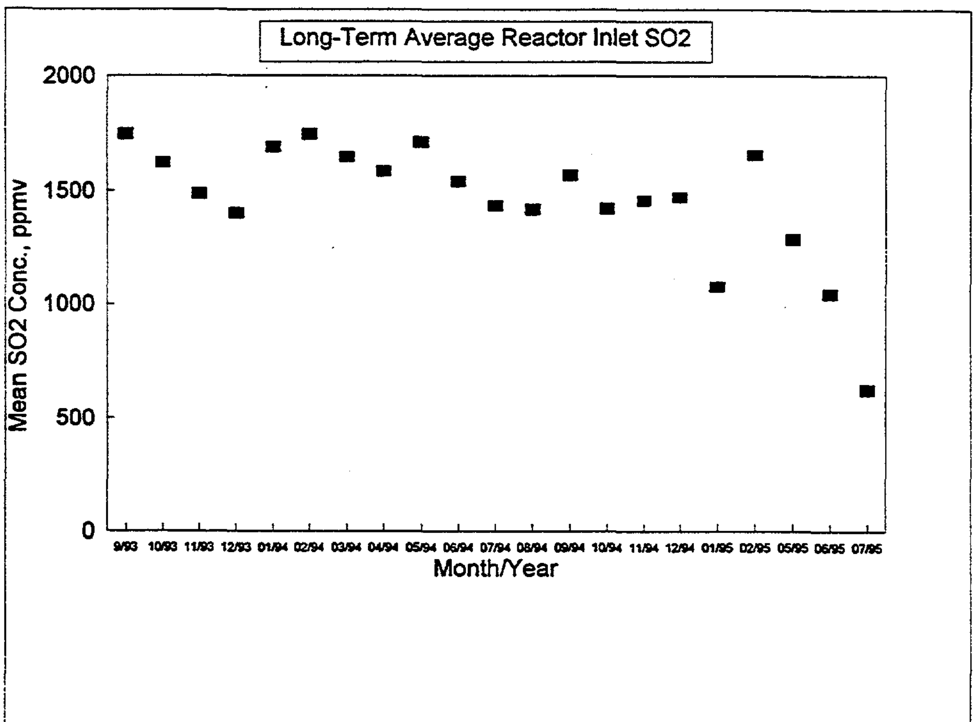

Figure 4-32. Monthly Average Reactor Inlet SO_2 Concentration During the SCR Demonstration Project

5.0 Aqueous Stream Monitoring Results

Aqueous stream monitoring was conducted on two streams: supplemental monitoring of the air preheater wash water (associated with the SCR reactor air preheaters) and compliance monitoring of the ash pond discharge stream. The results for each stream are summarized below.

5.1 Supplemental Monitoring

The air preheaters were washed several times during the program, and the wash water was sampled during these episodes. Because of the equipment configuration, however, it was very difficult to collect samples, during the in-situ washes, that were considered to be representative of the wash water that would be produced in a commercial unit. As a result, most of the wash water samples were not analyzed. During one wash cycle, however, the air preheater baskets were removed and washed, allowing much greater control of the wash water sample collection. The water samples collected during this wash cycle were analyzed, and the results are summarized in Table 5-1. Samples were obtained at the beginning and end of the wash cycle, which was performed using plant clear water (well water). Of note are the decrease in iron, sulfate, and fluoride concentrations and the increase in pH and chloride ion concentrations over the course of the wash cycle.

Table 5-1. Air Preheater Wash Water Analyses

Parameter	Units	Feb 9, 1995 1:00 p.m.	Feb 9, 1995 3:00 p.m.
pH	S.U.	2.97	4.78
Iron	mg/L	49.7	0.54
Fluoride	mg/L	0.12	<0.1
Chloride	mg/L	3.50	8.25
Sulfate	mg/L	728.0	6.02

5.2 Compliance Monitoring

Of the existing permitted aqueous discharge streams at Plant Crist, the only one that could possibly have been affected by the SCR demonstration project was the ash pond discharge stream. The parameters and schedule for compliance monitoring of this stream are specified in

U.S. EPA NPDES Permit No. FL0002275 and in the State of Florida Department of Environmental Regulation Operating Permit No. IO17-109985. Table 5-2 summarizes the results of ash pond discharge monitoring conducted during the period of the SCR demonstration: January 1993 through July 1995. These data were taken from Discharge Monitoring Reports submitted by Gulf Power Co. in compliance with permit requirements. As shown, the only exceedances of ash pond discharge permit limits occurred during the December 1994 and July 1995 monitoring periods.

In December 1994, the pH was lower than 6.0 for a period of approximately four hours during a wash cycle of the Unit 5 air preheater. During this excursion, the measured pH of the main plant discharge remained above the permit limit of 6.0. In July 1995, the total suspended solids exceeded both monthly average and daily maximum limits; this was caused by excessive rainfall. In August 1995, the measured TSS level was below the permit limits. Neither of these exceedances was related to operation of the SCR demonstration unit.

Table 5-2. Ash Pond Discharge Monitoring Summary

Month/Year	pH, S. U.		TSS, mg/L		Oil & Grease, mg/L	
	Minimum	Maximum	Monthly Average	Maximum	Monthly Average	Maximum
Jan 1993	6.62	9.30	3.9	5.6	<1.0	<1.0
Feb 1993	6.55	9.95	8.3	22.0	<1.0	<1.0
Mar 1993	6.53	9.85	8.5	19.0	<1.0	<1.0
Apr 1993	7.63	9.26	3.9	7.2	<1.0	<1.0
May 1993	7.80	8.73	4.2	7.0	<1.0	<1.0
Jun 1993	6.58	9.83	2.0	2.6	<1.0	<1.0
Jul 1993	6.37	9.50	3.4	8.2	<1.0	<1.0
Aug 1993	6.50	8.62	3.3	6.4	<1.0	<1.0
Sep 1993	7.50	9.43	3.6	8.2	1.0	1.0
Oct 1993	7.00	9.60	12.1	34.1	<1.0	<1.0
Nov 1993	6.41	9.00	5.7	10.0	<1.0	<1.0
Dec 1993	6.70	9.78	2.7	4.4	<1.0	<1.0
Jan 1994	6.45	8.13	7.2	22.0	<1.0	<1.0
Feb 1994	6.41	9.90	17.6	32.0	<1.0	<1.0
Mar 1994	6.29	9.79	17.9	59.0	<1.0	<1.0
Apr 1994	6.75	9.13	3.5	4.2	<1.0	<1.0
May 1994	6.87	9.76	6.7	16.0	<1.0	<1.0
Jun 1994	6.64	9.91	2.6	3.6	<1.0	<1.0
Jul 1994	6.43	9.38	4.7	5.6	<1.0	<1.0
Aug 1994	6.90	9.53	2.7	4.0	<1.0	<1.0
Sep 1994	6.57	9.69	4.0	7.2	<1.0	<1.0
Oct 1994	6.86	9.99	3.1	5.4	<1.0	<1.0
Nov 1994	6.55	9.47	2.8	4.2	<1.0	<1.0
Dec 1994	4.60 [a]	10.17	3.0	5.2	<1.0	<1.0
Jan 1995	6.67	10.20	3.6	4.8	<1.0	<1.0
Feb 1995	6.88	10.42	10.2	24.0	<1.0	<1.0
Mar 1995	6.94	9.87	7.1	17.0	<1.0	<1.0
Apr 1995	6.40	9.54	8.9	19.0	<1.0	<1.0
May 1995	6.91	9.75	9.6	15.0	<1.0	<1.0
Jun 1995	7.46	10.00	2.8	4.0	<1.0	<1.0
Jul 1995	8.20	9.51	51.6 [b]	200.0 [b]	<1.0	<1.0
Permit Limits	6.0	10.5	30.0	73.0	7.0	11.0

[a] Exceeded during Unit 5 air preheater wash. Returned to >6.0 within four hours. Measured pH of main plant discharge remained >6.0.
[b] High due to 5.5 inches of rainfall on sampling date. Subsequent samples collected August 1 and August 9, 1995: 8.8 mg/L and 11 mg/L, respectively.
Source: Discharge Monitoring Reports submitted by Gulf Power Co.

6.0 Solid Stream Monitoring Results

The coal feed to the Unit 5 boiler was the only solid stream monitored during the SCR demonstration project (with the exception of the fly ash streams discussed previously in the gas stream monitoring section). Table 6-1 presents a statistical summary of the coal ultimate analyses and chlorine measurements conducted during the SCR demonstration project's testing phase. The statistics shown were calculated based on the monthly average data shown in Appendix A, Table A-12. These data were obtained from Southern Company Services' Final Report (2). Relative variations were highest for chlorine and sulfur content.

Table 6-1. Coal Monitoring Results

Parameter	Units	Mean	Std. Dev.	Range
Carbon	wt %	74.82	0.81	73.29 - 77.40
Hydrogen	wt %	5.00	0.07	4.81 - 5.11
Nitrogen	wt %	1.58	0.03	1.52 - 1.66
Sulfur	wt %	2.58	0.40	1.14 - 3.02
Ash	wt %	9.30	0.63	7.75 - 10.55
Oxygen	wt %	6.73	0.66	5.53 - 7.98
Chlorine	ppmw	1767	812	185 - 3403

7.0 Health and Safety Considerations

Anhydrous ammonia was stored and used at Plant Crist during this program. The ammonia was stored in a 1000-gallon tank with a maximum fill level of 850 gallons. This tank was constructed in accordance with the ASME Code for Unfired Pressure Vessels (Section VIII), and was inspected, tested, and certified by an inspector qualified by the National Board of Boiler and Pressure Vessel Inspectors prior to shipment to Plant Crist.

The tank was equipped with a dual safety relief valve system. The storage tank was segregated from plant personnel, i.e., it was located in an area that was not frequented by plant personnel. The area was equipped with safety showers that were inspected on a monthly schedule. Material Safety Data Sheets for ammonia were included in all the design documents and in the plant safety program.

Plant Crist employed design, construction, and operating practices that met or exceeded industry standards for storing and handling anhydrous ammonia. Ammonia leak detection equipment was readily available, and water wash stations were located near the storage tank. The procurement, installation, loading, and unloading of the ammonia storage tank was handled by an experienced, licensed contractor. The transfer of liquid ammonia to the tank, and the displacement of vapor back to the truck was accomplished in a closed loop fashion, and no emissions were detected during these transfers. Metering and dilution of the ammonia was performed within an existing, unused stack for personnel protection.

These measures were very effective in preventing any spills or significant leaks of the ammonia. One small leak occurred in the area of the storage tanks. This leak, due to a poor hose connection, happened during the transfer of ammonia from the delivery truck to the storage tank. The operator saw the leak almost immediately, stopped the transfer, and reconnected the hose properly. Only a very small amount of ammonia was lost.

Two very small leaks occurred in the small diameter piping/tubing associated with the metering and dilution system within the unused stack. These leaks were too small to be detected by area monitoring devices. Instead, they were found by operating personnel who detected slight odors of ammonia within the stack and in the vicinity of the metering system. The leak sites were located with portable detection devices and quickly repaired.

8.0 Quality Assurance/Quality Control

A quality assurance/quality control program was conducted by SRI during the SCR demonstration project. A copy of the written Quality Assurance Program Plan (QAPP) was included as an appendix to the project's Environmental Monitoring Plan. The elements of this plan are briefly summarized below.

- Sampling Procedures. In general, applicable EPA reference methods were used to collect samples. These methods are described in detail in *Title 40 Code of Federal Regulations, Part 60, Appendix A*, and are summarized in Section 3 of this report. These established methods were used over the duration of the demonstration project.

- Analytical Procedures. Established EPA or ASTM reference methods, as listed in Section 3 of this report, were used to analyze all samples collected during the demonstration project. These methods establish the proper use of standards, blanks, matrix spikes, replicates, and calibration curves.

- Sample Custody. Procedures for tracking the handling and possession of each sample from collection through analysis and storage were followed as described in the QAPP. These procedures included guidelines for sample labeling, logging, record keeping, and review procedures.

- Calibration Procedures and Frequency. Flow measurement orifices, pitot tubes, manometers, and analytical balances were calibrated periodically during the demonstration program, using the procedures and frequencies described in the QAPP.

- Data reduction, Validation, and Reporting. Procedures were established and followed to protect the integrity of the reported results, as set out in the QAPP.

- Performance and Systems Audits. Periodic reviews of the total sampling and analytical system and of the capabilities of the measurement systems were conducted. Quarterly reports were submitted detailing the results of these audits.

A statistical analysis of the results for sample and analytical replicates was conducted, in which the relative standard deviation (RSD) was computed for the major parameters included in this report. The RSD is defined as the standard deviation divided by the mean value for a given parameter, and is a measure of data scatter. The results are summarized in Table 7-1. For most parameters, the average RSD was less than 10 percent. Higher RSDs were found for the concentrations of some species (e.g., N_2O, SO_3, slip NH_3, and reactor outlet NO_x for test conditions leading to high control efficiencies). Since these species were present at low concentrations, relatively small differences in the absolute concentration led to large RSD values in some cases.

Table 8-1. Summary of Relative Standard Deviations for Replicates

Parameter	Relative Standard Deviation [a], %	
	Average RSD, %	Range
Particulate Matter Loading		
Reactor Outlet	3.5	0.0 – 15.0
Air Preheaters	8.9	4.6 – 15.9
Ammonia Loss Tests (without catalyst) - Inlet & Outlet NH_3 Concentrations		
Reactor B	9.8	5.5 – 18.0
Reactor E	6.4	2.6 – 13.5
SO_2 Conversion Tests		
SO_2 Concentration	2.7	0.3 – 10.1
SO_3 Concentration	16.0	0.9 – 59.1
Parametric Test Series 1-5		
Slip NH_3 Concentration	15.7	0.0 – 93.8
SO_3 Concentration	20.5	1.3 – 119.8
SO_2 Concentration	2.6	0.1 – 16.3
HCL Concentration	5.7	0.3 – 22.6
NO_x - Inlet Concentration	2.4	0.0 – 53.5
NO_x - Outlet Concentration	19.4	0.0 – 200.0
N_2O	17 [b]	10 – 30 [b]

[a] Relative Standard Deviation is defined as the standard deviation divided by the mean value.

[b] Estimated assuming precision of 0.3 ppm.

9.0 Compliance Reporting

Discharge Monitoring Reports containing the monitoring results for the permitted ash pond discharge were submitted by Gulf Power Co. in Discharge Monitoring Reports as specified in the U.S. EPA NPDES Permit No. FL0002275 and in the State of Florida Department of Environmental Regulation Operating Permit No. IO17-109085. Monitored parameters included pH, total suspended solids, and oil and grease. Copies of these reports have been included as appendices to the quarterly and annual EMP reports for the SCR demonstration project, and the results are summarized in Section 5.

10.0 Results and Conclusions

The following is a summary of the EMP results obtained during the SCR Demonstration Project at Plant Crist:

- Apparent NO_x reduction efficiencies measured during the parametric tests showed that all of the SCR catalysts were capable of reductions from 50 to 100%, depending on reactor operating conditions. The mean reduction and observed range for each reactor based on parametric test data are summarized below:

Reactor	Apparent NO_x Reduction Efficiencies, %		NH_3 Slip, ppmv
	Mean	Range	Range
A	79.9	61.8 – 94.1	0.8 - 29
B	84.5	66.9 – 99.8	<0.7 - 35.3
C	88.9	69.5 – 99.2	0.8 - 58
D	89.1	80.9 – 96.7	<1.3 - 94.1
E	81.7	62.0 – 93.9	<0.1 - 68
F	84.7	70.6 – 96.0	<0.8 - 90.1
G	78.2	64.3 – 88.8	<0.7 - 94.1
J	68.7	51.2 – 85.7	<0.8 - 24.4

These reduction efficiencies should not be construed as necessarily reflecting the relative performance of the different catalysts in the reactors. Many factors impact the NO_x reduction efficiencies, and all of the reactors may not have experienced the same sequence of test parameters. In many cases, very high reductions efficiencies were achieved at conditions that may not be practical in routine operation. For example, at very high NO_x reduction efficiencies, ammonia slip could be as high as 90 ppmv. The ranges of ammonia slip measured during the parametric test sequences are also included in the table.

- In general, changes to the major SCR reactor operating parameters had the following impacts:

  — Increasing the ammonia-to-nitrogen oxide ratio resulted in increased NO_x reduction efficiency and increased ammonia slip.

  — Increasing reactor residence time (i.e., reducing the flue gas flow rate) resulted in increased NO_x reduction efficiency and reduced ammonia slip.

- Increasing reactor temperature did not have a definitive impact on NO_x reduction efficiency, but ammonia slip was reduced.

- The SO_3 concentration in the flue gas generally increased slightly across the SCR reactors, due to conversion of a portion of the SO_2. The fraction of SO_2 converted tended to increase with increasing reactor temperature and residence time. In many cases there was a slight decrease in SO_2 conversion as catalyst exposure time increased.

- N_2O concentrations upstream and downstream of the SCR reactors were all low, with the observed range varying from 1 to about 3 ppmv. No consistent trend toward increasing or decreasing concentration across the SCR reactors was observed; in many cases, there was no significant change in N_2O concentration between the SCR reactor inlet and outlet.

- An apparent increase in HCl concentration across the SCR reactors appeared to be an artifact of the sampling methods used for the SCR reactor inlet and outlet streams.

- The particulate matter loading was apparently higher at the SCR reactor outlets than at the ESP inlet upstream of the reactors. However, the ESP inlet loading measurements appeared to be low, based on subsequent measurements made in the economizer bypass duct at low boiler load conditions. As expected, the average loading was higher at high load than at low load (i.e., 3.9 and 3.5 gr/dscf @ 3% O_2, respectively).

- Good agreement was observed in both particulate matter size distribution and composition at the main reactor inlet and downstream of the last catalyst level for each of the SCR reactors.

- Based on the results of the TCLP analyses of the fly ash samples obtained at the SCR reactor inlet, outlet, or air preheater outlet, no significant change was noted across the SCR reactors, and none of these solids would be classified as hazardous under Title III of RCRA, with respect to the toxic metals.

- As expected, the SCR demonstration project did not have any detectable impact on the measured water quality parameters for the ash pond discharge stream.

- The ammonia storage and delivery system design was effective in minimizing the inadvertent release of ammonia.

11.0 References

1. Radian Corporation, *Environmental Monitoring Plan (EMP) Southern Company Services Selective Catalytic Reduction Project at Plant Crist, Pensacola, Florida*, Revised March 1993.

2. Southern Company Services, Inc., *Innovative Clean Coal Technology (ICCT) Demonstration of Selective Catalytic Reduction (SCR) Technology for the Control of Nitrogen Oxide (NO_x) Emissions from High-Sulfur Coal-Fired Boilers, Volumes 1-3.* Final Report. October 1996.

3. Southern Research Institute, *Testing and Analytical Services for the Innovative Clean Coal Technology Demonstration of Selective Catalytic Reduction (SCR) Technology for the Control of Nitrogen Oxide (NO_x) Emissions from High Sulfur Coal, Final Report for Task 1: Commissioning without Catalysts and without Ammonia Injection.* Draft Report, September 30, 1993.

4. Southern Research Institute, *Testing and Analytical Services for the Innovative Clean Coal Technology Demonstration of Selective Catalytic Reduction (SCR) Technology for the Control of Nitrogen Oxide (NO_x) Emissions from High Sulfur Coal, Final Report for Task 2: Commissioning without Catalysts and with Ammonia Injection.* Draft Report, December 15, 1993.

5. Southern Research Institute, *Testing and Analytical Services for the Innovative Clean Coal Technology Demonstration of Selective Catalytic Reduction (SCR) Technology for the Control of Nitrogen Oxide (NO_x) Emissions from High Sulfur Coal, Task 3A: Commissioning with Catalyst and without Ammonia Injection and Task 3B: Preliminary Parametric Test, Parts 1-6*, Final Report, October 6, 1995.

6. Southern Research Institute, *Testing and Analytical Services for the Innovative Clean Coal Technology Demonstration of Selective Catalytic Reduction (SCR) Technology for the Control of Nitrogen Oxide (NO_x) Emissions from High Sulfur Coal, Interim Report for Task 4: Long-Term Parametric Tests, 2nd Sequence, Parts 1-7.* Draft Report, August 31, 1994.

7. Southern Research Institute, *Testing and Analytical Services for the Innovative Clean Coal Technology Demonstration of Selective Catalytic Reduction (SCR) Technology for the Control of Nitrogen Oxide (NO_x) Emissions from High Sulfur Coal, Task 4: Third Long-Term Parametric Test, Parts 1-8.* Final Report, November 22, 1995.

8. Southern Research Institute, *Testing and Analytical Services for the Innovative Clean Coal Technology Demonstration of Selective Catalytic Reduction (SCR) Technology for the Control of Nitrogen Oxide (NO_x) Emissions from High Sulfur Coal, Interim Report for Task 4: Long-Term Parametric Tests, 4th Sequence, Parts 1-8.* Draft Report, April 15, 1995.

9. Southern Research Institute, *Testing and Analytical Services for the Innovative Clean Coal Technology Demonstration of Selective Catalytic Reduction (SCR) Technology for the Control of Nitrogen Oxide (NO_x) Emissions from High Sulfur Coal, Task 4: Fifth Long-Term Parametric Test, Parts 1-8*. Final Report, January 31, 1996.

10. Southern Research Institute, *Testing and Analytical Services for the Innovative Clean Coal Technology Demonstration of Selective Catalytic Reduction (SCR) Technology for the Control of Nitrogen Oxide (NO_x) Emissions from High Sulfur Coal, Effects of SCR Ammonia on Ammonia Volatilization, Ammonia Extraction, and Metals Extraction from SCR Fly Ash*. Final Report, October 25, 1995.

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Monitoring Data Summary Tables

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Table A-1. SCR Reactor Outlet Particulate Matter Loading Data

Test No./ Sequence	Reactor	Date	Load, MW	Oxygen, vol%	PM, gr/dscf
1	A	1 June 1993	84	3.0	4.01
		2 June 1993	84	3.1	3.81
		3 June 1993	43	7.9	3.59
		3 June 1993	43	7.8	3.60
	B	1 June 1993	84	2.5	4.21
		1 June 1993	84	3.1	4.05
		3 June 1993	43	7.5	3.41
		3 June 1993	43	7.7	3.41
	C	7 June 1993	84	2.4	3.77
		7 June 1993	84	2.5	3.91
		3 June 1993	43	7.6	3.53
		3 June 1993	43	7.4	3.49
	D	14 May 1993	84	5.7	3.18
		14 May 1993	84	5.2	3.08
		4 June 1993	43	9.3	3.52
		4 June 1993	43	9.2	3.39
	E	27 May 1993	84	3.3	4.31
		2 June 1993	84	4.8	4.08
		4 June 1993	43	8.6	3.85
		4 June 1993	43	8.4	3.90
	F	27 May 1993	84	5.0	4.84
		2 June 1993	84	3.9	3.91
		4 June 1993	43	8.7	3.67
		4 June 1993	43	8.9	3.81
	G	27 May 1993	84	4.6	3.94
		27 May 1993	84	3.9	3.81
		3 June 1993	43	8.6	3.30
		3 June 1993	43	8.6	3.28
	H	27 May 1993	84	4.2	3.96
		27 May 1993	84	4.0	3.54
		4 June 1993	43	8.7	3.48
		4 June 1993	43	8.1	3.09
4-1	A	21 September 1993	90	1.5	3.97
		21 September 1993	90	1.5	3.94
		22 September 1993	90	1.6	5.66
		22 September 1993	90	1.6	6.82
		22 September 1993	90	1.6	4.55
		21 September 1993	90	1.5	4.17

Table A-1 (continued)

Test No./ Sequence	Reactor	Date	Load, MW	Oxygen, vol%	PM, gr/dscf
4-1 Cont'd	B	14 July 1993	64	6.1	3.53
		14 July 1993	64	6.1	3.53
		14 July 1993	64	6.1	3.50
		14 July 1993	64	6.1	3.05
		14 July 1993	64	6.1	3.40
		14 July 1993	64	6.1	3.36
		15 July 1993	84	6.1	5.22
		15 July 1993	84	6.1	5.14
		15 July 1993	84	6.1	4.50
		15 July 1993	84	6.1	4.82
		15 July 1993	84	6.1	5.02
		15 July 1993	84	6.1	5.26
	C	16 July 1993	84	3.5	5.13
		16 July 1993	84	3.5	4.51
		16 July 1993	84	3.5	4.93
		16 July 1993	84	3.5	4.88
		16 July 1993	84	3.5	4.48
		16 July 1993	84	3.5	4.67
	D	28 October 1993	84	3.5	3.12
		29 October 1993	84	3.5	2.87
		29 October 1993	84	3.5	2.67
	E	28 October 1993	84	3.5	3.30
		29 October 1993	84	3.5	2.96
		29 October 1993	84	3.5	3.92
	F	28 October 1993	84	3.5	3.69
		29 October 1993	84	3.5	3.78
		29 October 1993	84	3.5	4.55
4-2	A	4 February 1994	84	2.8	3.87
		4 February 1994	84	2.8	3.44
		4 February 1994	84	2.8	3.19
		4 February 1994	84	2.8	3.44
		4 February 1994	84	2.8	3.48
	B	7 February 1994	84	2.7	3.78
		7 February 1994	84	2.7	2.71
		7 February 1994	84	2.7	3.06
		7 February 1994	84	2.7	2.78
		7 February 1994	84	2.7	3.76
	C	9 February 1994	84	3.1	3.75
		9 February 1994	84	3.1	3.31
		9 February 1994	84	3.1	3.05

Table A-1 (continued)

Test No./ Sequence	Reactor	Date	Load, MW	Oxygen, vol%	PM, gr/dscf
4-2 Cont'd	C	9 February 1994	84	3.1	3.21
		9 February 1994	84	3.1	3.04
	D	10 February 1994	84	5.4	4.13
		10 February 1994	84	5.4	3.31
	E	21 February 1994	84	4.8	4.66
		21 February 1994	84	4.8	5.85
	F	21 February 1994	84	4.4	8.61
		21 February 1994	84	4.4	7.13
4-4	A	6 December 1994	84	3.30	4.05
		6 December 1994	84	3.78	3.68
		6 December 1994	84	3	3.64
		6 December 1994	84	3.1	4.35
		6 December 1994	84	3.6	3.62
	B	10 November 1994	84	3	3.33
		10 November 1994	84	2.9	3.01
		10 November 1994	84	2.5	3.27
		10 November 1994	84	3.4	3.34
		10 November 1994	84	4.3	3.41
	C	11 November 1994	84	2.86	3.64
		11 November 1994	84	2.80	3.66
		11 November 1994	84	2.90	3.42
		11 November 1994	84	4.8	3.28
		11 November 1994	84	3.6	3.08
	D	7 December 1994	84	4.3	4.52
		7 December 1994	84	4.5	3.95
	E	7 December 1994	84	3.6	4.08
		7 December 1994	84	3.4	4.42
	F	5 December 1994	84	3.5	4.23
		5 December 1994	84	3.1	4.46
	G	5 December 1994	84	3.3	3.06
		5 December 1994	84	3.1	3.56

Table A-2. Particulate Matter Loading Data—Air Preheaters

Reactor No.	Test Location	Date	PM (gr/dscf)
A	Air Preheater Inlet	25 Apr 1994	3.9
		25 Apr 1994	3.6
		25 Apr 1994	3.0
		8 Nov 1994	2.6
		8 Nov 1994	3.4
		8 Nov 1994	3.5
	Air Preheater Outlet	25 Apr 1994	3.5
		25 Apr 1994	3.3
		25 Apr 1994	2.8
		9 Jun 1994	2.6
		9 Jun 1994	2.4
		9 Jun 1994	2.5
		8 Nov 1994	2.7
		8 Nov 1994	2.7
		8 Nov 1994	2.6
B	Air Preheater Inlet	2 May 1994	3.4
		2 May 1994	3.3
		2 May 1994	3.5
		9 Nov 1994	3.9
		9 Nov 1994	3.5
		9 Nov 1994	3.4
	Air Preheater Outlet	2 May 1994	2.7
		2 May 1994	2.7
		2 May 1994	2.9
		10 Jun 1994	2.4
		10 Jun 1994	2.3
		10 Jun 1994	2.3
		9 Nov 1994	2.5
		9 Nov 1994	2.4
C	Air Preheater Inlet	26 Apr 1994	3.6
		26 Apr 1994	3.9
		26 Apr 1994	4.0

Table A-3. Ash Minerals Analysis Summary[a]

Species	As-Fired Coal		ESP Inlet		Reactor A Outlet		Reactor B Outlet	
	10 Feb 1993	11 Feb 1993	9 Feb 1993	10 Feb 1993	25 Apr 1994	8 Nov 1994	2 May 1994	9 Nov 1994
SiO_2	44.3	47.4	48.9	48.4	48.0	47.59	49.3	47.58
Al_2O_3	22.6	22.5	22.7	22.7	22.2	23.73	22.3	24.77
TiO_2	0.83	0.83	1	1	1.1	1.15	1.1	1.2
Fe_2O_3	19.9	20.6	17.8	18.1	18.7	16.81	18.5	16.82
CaO	4.6	2.8	4.6	4	3.5	2.93	2.9	2.54
MgO	0.91	0.78	0.97	0.97	0.98	0.91	1	1.06
K_2O	2.3	2	2.8	2.5	2.4	2.76	2.4	2.92
Na_2O	0.8	0.66	0.79	0.87	0.97	0.94	1.2	0.98
SO_3	4	2.5	0.99	1.2	1.1	0.79	0.78	0.69
P_2O_5	0.18	0.16	0.18	0.16	0.14	0.49	0.14	0.59
Li_2O	0.02	0.02	0.02	0.02	0.03	NA	0.03	NA
SrO	NA	NA	NA	NA	NA	0.08	NA	0.1
BaO	NA	NA	NA	NA	NA	0.1	NA	0.12
MnO	NA	NA	NA	NA	NA	0.11	NA	0.1
Undetermined	NA	NA	NA	0.08	0.88	1.61	0.35	0.53

Species	APH[b] A Outlet		APH B Outlet		APH C Inlet
	25 Apr 1994	8 Nov 1994	2 May 1994	9 Nov 1994	26 Apr 1994
SiO_2	47.4	48.58	49.3	48.36	49.0
Al_2O_3	22.0	24.03	21.7	25.04	21.9
TiO_2	1.1	1.15	0.91	1.24	0.91
Fe_2O_3	20.3	16.61	18.2	15.18	18.5
CaO	3.7	2.98	2.9	2.51	3.3
MgO	0.97	0.93	0.97	0.93	1.0
K_2O	2.2	2.81	2.5	2.96	2.5
Na_2O	0.91	0.96	1.1	1.04	0.91
SO_3	1.0	0.88	0.27	0.95	0.78
P_2O_5	0.14	0.49	0.15	0.59	0.14
Li_2O	0.03	NA	0.03	NA	0.04
SrO	NA	0.08	NA	0.1	NA
BaO	NA	0.07	NA	0.07	NA
MnO	NA	0.09	NA	0.1	NA
Undetermined	0.25	0.34	1.97	0.93	1.02

[a] Units: % by weight.
[b] APH = Air preheater.

Table A-4. Trace Metals Concentrations in Ash Samples[a]

Element	ESP Inlet		ESP Outlet		Reactor A Inlet		Air Preheater A		Air Preheater B	
							Inlet	Outlet	Inlet	Outlet
	9 Feb 1993 High Load	11 Feb 1993 Low Load	9 Feb 1993 High Load	11 Feb 1993 Low Load	6 Mar 1993 High Load	6 Mar 1993 Low Load	8 Nov 1994	8 Nov 1994	9 Nov 1994	9 Nov 1994
Antimony	9	2.9	<180.0	<3.6	6.1	8.3	15	12	12	17.3
Arsenic	139	69.7	110	97.9	51.3	47.2	145	146	146	171
Barium	298	377	339	563	302	259	305	357	455	431
Beryllium	11.3	14.5	<35.0	21	9.6	10.3	17.6	17.3	17.7	18.2
Cadmium	5.9	10.3	39.1	20	4.6	7.2	4.3	<4.0	<4.0	<4.0
Cesium	85.5	74.6	<3500	<80.0	72.9	69.9	<33	<32	<32	<31
Chromium	124	148	241	152	132	124	148	151	151	168
Cobalt	23	30.6	<70.0	30.7	27.4	22.8	50.6	50.1	53.8	54.1
Copper	71.6	86.4	215	93.2	66.2	65.4	125	125	144	148
Lead	221	286	426	404	227	239	298	227	277	319
Manganese	152	172	226	174	225	169	173	168	158	160
Mercury	0.35	0.13	<7.0	0.21	0.12	0.18	0.019	0.63	<0.010	1.29
Molybdenum	72.9	77	880	85.7	82.6	74.6	26.3	25.2	25.3	27.8
Nickel	86.5	104	<180	106	100	89.5	156	157	167	179
Rubidium	134	126	<1800	125	132	123	93.2	117	155	142
Selenium	99.3	8.02	514	13.7	1.37	7.1	<0.56	3.7	<0.54	6.7
Strontium	186	237	228	252	188	175	472	546	766	736
Tin	26.8	31.1	<180	22.7	21.5	20	78.2	83.9	93.1	75.8
Vanadium	683	458	577	428	467	531	348	348	368	380
Zinc	311	647	3320	1118	436	353	247	252	227	241

[a] Units: µg/g (ppmw).

Table A-5. Ammonia Concentration Across Reactors Without Catalyst

Reactor	Position	Date	Temperature, ° F	Flow Rate, kwscfm	O_2, Volume %	NH_3, wppmv @ 3% O_2
B	Inlet	9 June 1993	750	7.5	2.52	228.1
	Inlet	9 June 1993	750	7.5	2.55	180.7
	Outlet	9 June 1993	750	7.5	2.61	184.8
	Outlet	9 June 1993	750	7.5	2.86	218.3
	Outlet	9 June 1993	750	7.5	2.86	203.4
	Inlet	9 June 1993	750	3.0	2.55	191.6
	Inlet	9 June 1993	750	3.0	2.54	213.7
	Inlet	9 June 1993	750	3.0	2.48	193.8
	Outlet	9 June 1993	750	3.0	2.84	179
	Outlet	9 June 1993	750	3.0	3.15	166.8
	Outlet	9 June 1993	750	3.0	2.77	205.4
	Inlet	10 June 1993	620	7.5	2.8	202.7
	Inlet	10 June 1993	620	7.5	2.9	227.3
	Inlet	10 June 1993	620	7.5	2.97	157.6
	Outlet	10 June 1993	620	7.5	3.3	209.9
	Outlet	10 June 1993	620	7.5	2.98	231.5
	Outlet	10 June 1993	620	7.5	3.01	205.1
	Inlet	10 June 1993	620	3.0	2.84	214.9
	Inlet	10 June 1993	620	3.0	2.81	228.4
	Inlet	10 June 1993	620	3.0	2.69	199.1
	Outlet	10 June 1993	620	3.0	3.16	192.6
	Outlet	10 June 1993	620	3.0	3.87	209.4
	Outlet	10 June 1993	620	3.0	3.06	214
E	Inlet	9 June 1993	750	0.60	2.08	275.6
	Inlet	9 June 1993	750	0.60	2.19	278.3
	Inlet	9 June 1993	750	0.60	2.15	216.9
	Outlet	9 June 1993	750	0.60	2.68	233
	Outlet	9 June 1993	750	0.60	3.57	232.8
	Outlet	9 June 1993	750	0.60	2.85	244.3
	Inlet	9 June 1993	750	0.24	2.18	212.7
	Inlet	9 June 1993	750	0.24	2.12	192.3
	Inlet	9 June 1993	750	0.24	2.2	199.2
	Outlet	9 June 1993	750	0.24	3.28	210.7
	Outlet	9 June 1993	750	0.24	3.24	214
	Outlet	9 June 1993	750	0.24	3.31	203.5
	Inlet	10 June 1993	620	0.60	2.39	225.1
	Inlet	10 June 1993	620	0.60	2.46	227.8
	Inlet	10 June 1993	620	0.60	2.5	212.8
	Outlet	10 June 1993	620	0.60	2.98	232.6
	Outlet	10 June 1993	620	0.60	3.03	263.5

Table A-5 (continued)

Reactor	Position	Date	Temperature, ° F	Flow Rate, kwscfm	O_2, Volume %	NH_3, wppmv @ 3% O_2
E	Outlet	10 June 1993	620	0.60	3.04	256.8
	Inlet	10 June 1993	620	0.24	2.67	186.2
	Inlet	10 June 1993	620	0.24	3.66	228.7
	Inlet	10 June 1993	620	0.24	3.51	243.2
	Outlet	10 June 1993	620	0.24	3.55	237.6
	Outlet	10 June 1993	620	0.24	3.56	252.5
	Outlet	10 June 1993	620	0.24	3.45	236.2

Table A-6. SO_2 Oxidation Test Data

Reactor	Date	Target Reactor Operating Conditions				SO_2, dppmv @ 3% O_2		SO_3, dppmv @ 3% O_2	
		Test Condition Code	Temp., °F	Gas Rate, kwscfm	NH_3/NO_x	Inlet	Outlet	Inlet	Outlet
A	8/6/93	22	700	5.0	0.8	2,240	2,330	11.1	26.8
	8/6/93	17	700	3.0	0.8	2,590	2,418	8.3	38.1
	8/9/93	7	620	5.0	0.8	2,113	2,198	10.0	11.5
	8/9/93	27	700	7.3	0.8	2,084	2,075	12.7	34.4
	8/10/93	37	750	5.0	0.8	1,952	1,970	9.2	50
	8/11/93	42	750	7.3	0.8	2,122	2,234	14.7	40.6
	8/11/93	32	750	3.0	0.8	2,246	1,993	9.8	53.1
	8/12/93	2	620	3.0	0.8	1,892	2,093	11.3	15.1
	8/12/93	12	620	7.3	0.8	1,997	2,159	8.9	8.1
B	7/13/93	22	700	5.0	0.8	1,982	2,007	11.2	12.0
	7/21/93	12	620	7.3	0.8	2,287	3,189	10.3	8.4
	7/21/93	2	620	3.0	0.8	2,555	2,443	12.2	8.9
	7/22/93	27	700	7.3	0.8	2,061	2,029	13.1	22.0
	7/22/93	17	700	3.0	0.8	1,918	2,135	12.5	20.9
	7/23/93	32	750	3.0	0.8	2,213	2,061	20.5	34.1
	7/26/93	42	750	7.5	0.8	2,363	2,449	16.7	22.6
	7/26/93	37	750	5.0	0.8	2,392	2,495	14.1	27.1
	7/27/93	7	620	5.0	0.8	2,086	2,491	10.6	6.1
	8/3/93	12	620	7.3	0.8	1,906	1,985	7.7	12.4
	8/3/93	27	700	7.3	0.8	2,024	1,943	5.8	8.7

Table A-6 (continued)

Reactor	Date	Target Reactor Operating Conditions				SO_2, dppmv @ 3% O_2		SO_3, dppmv @ 3% O_2	
		Test Condition Code	Temp., °F	Gas Rate, kwscfm	NH_3/NO_x	Inlet	Outlet	Inlet	Outlet
C	7/12/93	22	700	5.0	0.8	2,025	2,186	11.4	37.3
	7/27/93	27	700	7.3	0.8	—[a]	2,571	—	21.4
	7/28/93	2	620	3.0	0.8	—	2,230	—	8.5
	7/28/93	7	620	5.0	0.8	—	2,486	—	10.4
	7/28/93	12	620	7.5	0.8	—	2,591	—	8.0
	7/29/93	37	750	5.0	0.8	—	2,208	—	72.5
	7/29/93	42	750	7.5	0.8	—	2,448	—	51.5
	7/30/93	32	750	3.0	0.8	—	2,395	—	77.5
	7/30/93	17	700	3.0	0.8	—	2,469	—	45.1
	8/5/93	7	620	5.0	0.8	—	2,463	—	—
	8/5/93	12	620	7.5	0.8	—	2,527	—	—
	8/5/93	2	620	3.0	0.8	—	2,401	—	6.4
	8/13/93	32	750	3.0	0.8	2,272	2,107	15.3	75.2
	8/13/93	37	750	5.0	0.8	2,148	2,261	12.1	54.7
	8/13/93	42	750	7.5	0.8	2,237	2,201	14.0	58.5

[a] Dash indicates that no tests were performed at these conditions.

Table A-7. Parametric Test Data—Test Sequence 1

Reactor	Date	Location	Target Reactor Operating Conditions				Average Concentration, dppmv @ 3% O_2			
			Test Condition Code	Temp., °F	Gas Rate, kwscfm	NH_3/NOx	NH_3	SO_2	SO_3	HCl
A	16Aug93	Outlet	16	700	3.0	0.6	1.0	—[a]	—	—
	17Aug93	Outlet	26	700	7.3	0.6	0.8	—	—	—
	18Aug93	Outlet	19	700	3.0	1.0	2.1	—	—	—
	23Sep93	Outlet	14	620	7.5	1.0	28.4	—	—	—
	23Sep93	Outlet	22	700	5.0	0.8	6.0	—	—	—
	10Sep93	Outlet	1	620	3.0	0.6	—	2,108	6.1	—
	10Sep93	Outlet	4	620	3.0	1.0	—	1,944	9.2	—
	13Sep93	Outlet	11	620	7.5	0.6	—	1,976	8.6	—
	13Sep93	Outlet	14	620	7.5	1.0	—	2,008	3.4	—
	24Sep93	Outlet	22	700	5.0	0.8	—	2,019	14.7	—
	24Sep93	Outlet	31	750	3.0	0.6	—	2,082	58.7	—
	24Sep93	Outlet	34	750	3.0	1.0	—	1,911	43.8	—
	24Sep93	Outlet	41	750	6.8	0.6	—	2,077	30.2	—
	27Sep93	Outlet	44	750	7.1	1.0	—	1,430	14.5	—
	06Aug93	Outlet	22	700	5.0	0.8	—	—	—	178
B	04Aug93	Outlet	22	700	5.0	0.8	6.8	—	—	—
	17Aug93	Outlet	19	700	3.0	1.0	1.8	—	—	—
	17Aug93	Outlet	22	700	5.0	0.8	0.7	—	—	—
	19Aug93	Outlet	26	700	7.5	0.6	0.9	—	—	—
	22Sep93	Outlet	14	620	7.5	1.0	35.3	—	—	—
	23Sep93	Outlet	22	700	5.0	0.8	1.0	—	—	—
	08Sep93	Outlet	1	620	3.0	0.6	—	1,994	6.2	—
	09Sep93	Outlet	4	620	3.0	1.0	—	2,064	4.6	—
	13Sep93	Outlet	11	620	7.5	0.6	—	2,046	6.8	—
	13Sep93	Outlet	14	620	7.5	1.0	—	2,105	2.6	—
	24Sep93	Outlet	22	700	5.0	0.8	—	1,438	2.2	—

Table A-7 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Average Concentration, dppmv @ 3% O_2			
			Test Condition Code	Temp., °F	Gas Rate, kwscfm	NH_3/NOx	NH_3	SO_2	SO_3	HCl
B	10Sep93	Outlet	31	850	3.0	0.9	—	1,901	26.4	—
	10Sep93	Outlet	34	750	3.0	1.0	—	1,840	18.3	—
	09Sep93	Outlet	41	750	7.5	0.6	—	2,029	23.4	—
	09Sep93	Outlet	44	750	7.5	1.0	—	2,029	10.0	—
	16Jul93	Outlet	22	700	5.0	0.8	—	—	—	152
C	18Aug93	Outlet	16	700	3.0	0.6	1.0	—	—	—
	19Aug93	Outlet	16	700	3.0	0.6	2.8	—	—	—
	12Aug93	Outlet	16	700	3.0	0.6	0.8	—	—	—
	12Aug93	Outlet	26	700	7.5	0.6	2.9	—	—	—
	17Aug93	Outlet	19	700	3.0	1.0	16.5	—	—	—
	21Sep93	Outlet	14	620	7.5	1.0	58.0	—	—	—
	23Sep93	Outlet	22	700	5.0	0.8	5.4	—	—	—
	08Sep93	Outlet	1	620	3.0	0.6	—	2,194	20.1	—
	09Sep93	Outlet	4	620	3.0	1.0	—	2,006	6.8	—
	24Sep93	Outlet	11	620	7.5	0.6	—	1,443	2.7	—
	10Sep93	Outlet	14	620	7.5	1.0	—	2,114	6.5	—
	27Sep93	Outlet	22	700	5.0	0.8	—	1,837	32.2	—
	08Sep93	Outlet	31	750	3.0	0.6	—	1,969	68.3	—
	13Sep93	Outlet	34	750	3.0	1.0	—	1,965	56.8	—
	13Sep93	Outlet	41	750	7.5	0.6	—	2,057	40.4	—
	10Sep93	Outlet	44	750	7.5	1.0	—	1,986	29.0	—
	14Jul93	Outlet	22	700	5.0	0.8	—	—	—	137
	15Jul93	Outlet	22	700	5.0	0.8	—	—	—	143
	19Jul93	Outlet	22	700	5.0	0.8	—	—	—	125
D	25Oct93	Outlet	14	620	0.60	1.0	90.4	—	—	—
	26Oct93	Outlet	22	700	0.40	0.8	2.8	—	—	—

Table A-7 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Average Concentration, dppmv @ 3% O_2			
			Test Condition Code	Temp., °F	Gas Rate, kwscfm	NH_3/NOx	NH_3	SO_2	SO_3	HCl
D	20Oct93	Outlet	1	620	0.24	0.6	—	2,336	7.7	—
	21Oct93	Outlet	22	700	0.40	0.8	—	2,096	26.5	—
	15Oct93	Outlet	31	750	0.24	0.6	—	1,717	34.8	—
	22Oct93	Outlet	34	750	0.24	1.0	—	2,578	49.6	—
	19Oct93	Outlet	41	750	0.60	0.6	—	1,886	25.6	—
	19Oct93	Outlet	44	750	0.60	1.0	—	1,902	17.4	—
	27Oct93	Outlet	1	700	0.40	0.8	—	—	—	135
E	25Oct93	Outlet	14	620	0.60	1.0	68.0	—	—	—
	26Oct93	Outlet	22	700	0.40	0.8	<0.13	—	—	—
	20Oct93	Outlet	1	620	0.24	0.6	—	2,104	6.9	—
	21Oct93	Outlet	22	700	0.40	0.8	—	2,058	15.8	—
	22Oct93	Outlet	31	750	0.24	0.6	—	2,360	38.7	—
	22Oct93	Outlet	34	750	0.24	1.0	—	2,073	16.0	—
	19Oct93	Outlet	41	750	0.60	0.6	—	1,855	15.2	—
	19Oct93	Outlet	44	750	0.60	1.0	—	1,925	9.8	—
	27Oct93	Outlet	22	700	0.40	0.8	—	—	—	211
F	25Oct93	Outlet	14	620	0.60	1.0	32.5	—	—	—
	26Oct93	Outlet	22	700	0.40	0.8	76.7	—	—	—
	20Oct93	Outlet	1	620	0.24	0.6	—	1,808	3.6	—
	21Oct93	Outlet	22	700	0.40	0.8	—	1,806	8.7	—
	22Oct93	Outlet	31	750	0.24	0.6	—	2,006	12.0	—
	22Oct93	Outlet	34	750	0.24	1.0	—	2,028	10.0	—
	19Oct93	Outlet	41	750	0.60	0.6	—	1,679	10.1	—
	19Oct93	Outlet	44	750	0.60	1.0	—	1,690	7.1	—
	27Oct93	Outlet	1	700	0.40	0.8	—	—	—	202

[a] Dash indicates that no tests were performed at these conditions.

Table A-8. Parametric Test Data—Test Sequence 2

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
A	16Dec93	Outlet	22	700	5.0	0.8	—[a]	—	1.8	—	—	—	—
	05Jan94	Outlet	22	700	5.0	0.8	—	—	2.6	—	—	—	—
	10Jan94	Outlet	7	620	5.0	0.8	—	—	5.7	—	—	—	—
	10Jan94	Outlet	12	620	7.0	0.8	—	—	9.8	—	—	—	—
	12Jan94	Outlet	14	620	7.1	1.0	—	—	29	—	—	—	—
	07Jan94	Outlet	22	700	5.0	0.8	—	—	2.7	—	—	—	—
	07Jan94	Outlet	27	700	6.3	0.8	—	—	4.5	—	—	—	—
	11Jan94	Outlet	42	750	6.0	0.8	—	—	2.9	—	—	—	—
	27Jan94	Outlet	2	620	3.0	0.8	—	—	—	1,733	10.2	—	—
	27Jan94	Outlet	17	700	3.0	0.8	—	—	—	1,653	28.8	—	—
	26Jan94	Outlet	22	700	5.0	0.8	—	—	—	1,672	11.5	—	—
	26Jan94	Outlet	27	700	6.8	0.8	—	—	—	1,654	11.7	—	—
	25Jan94	Outlet	32	750	3.0	0.8	—	—	—	1,613	27.0	—	—
	25Jan94	Outlet	37	750	5.0	0.8	—	—	—	1,320	34.8	—	—
	28Jan94	Outlet	42	750	6.1	0.8	—	—	—	1,615	19.7	—	—
	28Jan94	Outlet	22	700	5.0	0.8	—	—	—	—	—	241	—
	20Apr94	Inlet	—	—	—	—	310	—	—	—	—	—	2.4
	20Apr94	Outlet	22	700	5.0	0.8	310	—	—	—	—	—	1.2
B	15Dec93	Outlet	22	700	5.0	0.8	—	—	2.9	—	—	—	—
	10Jan94	Outlet	7	620	5.0	0.8	—	—	<0.81	—	—	—	—
	10Jan94	Outlet	12	620	7.0	0.8	—	—	2.4	—	—	—	—
	12Jan94	Outlet	14	620	7.0	1.0	—	—	7.2	—	—	—	—
	05Jan94	Outlet	22	700	5.0	0.8	—	—	0.7	—	—	—	—
	07Jan94	Outlet	22	700	5.0	0.8	—	—	<0.8	—	—	—	—
	07Jan94	Outlet	27	700	6.6	0.8	—	—	0.9	—	—	—	—

Table A-8 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
B	11Jan94	Outlet	42	750	6.5	0.8	—	—	0.9	—	—	—	—
	17Mar94	Outlet	2	620	3.0	0.8	—	—	—	2,115	4.6	—	—
	17Mar94	Outlet	17	700	3.0	0.8	—	—	—	2,184	25.0	—	—
	18Mar94	Outlet	22	700	5.0	0.8	—	—	—	2,236	8.4	—	—
	21Mar94	Outlet	27	700	6.6	0.8	—	—	—	2,127	5.7	—	—
	21Mar94	Outlet	32	750	3.0	0.8	—	—	—	2,084	22.8	—	—
	21Mar94	Outlet	37	750	5.0	0.8	—	—	—	2,109	14.5	—	—
	21Mar94	Outlet	42	750	6.6	0.8	—	—	—	2,076	17.4	—	—
	01Feb94	Outlet	22	700	—	0.8	—	—	—	—	—	158	—
	20Apr94	Inlet	—	—	—	—	310	—	—	—	—	—	2.4
	20Apr94	Outlet	22	700	5	0.8	297	—	—	—	—	—	1.0
C	15Dec93	Outlet	22	700	5.0	0.8	—	—	2.7	—	—	—	—
	12Jan94	Outlet	7	620	5.0	0.8	—	—	2.8	—	—	—	—
	12Jan94	Outlet	12	620	7.5	0.8	—	—	7	—	—	—	—
	13Jan94	Outlet	14	620	7.5	1.0	—	—	14.1	—	—	—	—
	05Jan94	Outlet	22	700	5.0	0.8	—	—	1.4	—	—	—	—
	05Jan94	Outlet	27	700	7.4	0.8	—	—	3.1	—	—	—	—
	11Jan94	Outlet	42	750	7.2	0.8	—	—	4.4	—	—	—	—
	26Jan94	Outlet	2	620	3.0	0.8	—	—	—	1,725	8.9	—	—
	26Jan94	Outlet	17	700	3.0	0.8	—	—	—	1,670	32.2	—	—
	27Jan94	Outlet	22	700	5.0	0.8	—	—	—	1,682	24.8	—	—
	27Jan94	Outlet	27	700	7.5	0.8	—	—	—	1,650	12.3	—	—
	25Jan94	Outlet	32	750	3.0	0.8	—	—	—	1,643	65.1	—	—
	25Jan94	Outlet	37	750	5.0	0.8	—	—	—	1,638	49.9	—	—
	24Jan94	Outlet	42	750	7.3	0.8	—	—	—	1,720	33	—	—

Table A-8 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
C	28Jan94	Outlet	22	700	5	0.8	—	—	—	—	—	211	—
	20Apr94	Inlet	—	—	—	—	310	—	—	—	—	—	2.4
	20Apr94	Outlet	22	700	5	0.8	299	—	—	—	—	—	1.7
D	21Dec93	Outlet	22	700	0.40	0.8	—	—	3.1	—	—	—	—
	08Apr94	Outlet	7	620	0.40	0.8	—	—	<1.3	—	—	—	—
	14Apr94	Outlet	12	620	0.60	0.8	—	—	36.1	—	—	—	—
	14Apr94	Outlet	14	620	0.60	1.0	—	—	66.9	—	—	—	—
	15Apr94	Outlet	22	700	0.40	0.8	—	—	4.0	—	—	—	—
	15Apr94	Outlet	27	700	0.60	0.8	—	—	10.9	—	—	—	—
	18Apr94	Outlet	42	750	0.60	0.8	—	—	15.4	—	—	—	—
	03Mar94	Outlet	2	620	0.24	0.8	—	—	—	2,127	3.1	—	—
	23Feb94	Outlet	17	700	0.24	0.8	—	—	—	1,834	25.7	—	—
	02Feb94	Outlet	22	700	0.40	0.8	—	—	—	1,852	26.9	—	—
	02Mar94	Outlet	27	700	0.60	0.8	—	—	—	1,981	11.2	—	—
	02Mar94	Outlet	32	750	0.24	0.8	—	—	—	1,973	32.2	—	—
	24Feb94	Outlet	37	750	0.40	0.8	—	—	—	1,809	28.9	—	—
	01Mar94	Outlet	42	750	0.60	0.8	—	—	—	2,112	29.1	—	—
	02Feb94	Outlet	22	700	0.40	0.8	—	—	—	—	—	163	—
	19Apr94	Inlet	—	—	—	—	340	—	—	—	—	—	1.8
	19Apr94	Outlet	22	700	0.40	0.8	325	—	—	—	—	—	1.8
E	21Dec93	Outlet	22	700	0.40	0.8	—	—	<0.8	—	—	—	—
	01Apr94	Outlet	4	620	0.24	1.0	—	—	2.4	—	—	—	—
	07Apr94	Outlet	7	620	0.40	0.8	—	—	<1.0	—	—	—	—
	04Apr94	Outlet	12	620	0.60	0.8	—	—	1.4	—	—	—	—
	04Apr94	Outlet	14	620	0.60	1.0	—	—	7	—	—	—	—

Table A-8 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
E	05Apr94	Outlet	22	700	0.40	0.8	—	—	<1.3	—	—	—	—
	13Apr94	Outlet	27	700	0.60	0.8	—	—	<0.6	—	—	—	—
	05Apr94	Outlet	42	750	0.60	0.8	—	—	<1.2	—	—	—	—
	17Mar94	Outlet	2	620	0.24	0.8	—	—	—	2,111	13.9	—	—
	14Mar94	Outlet	17	700	0.24	0.8	—	—	—	1,980	20.3	—	—
	14Mar94	Outlet	22	700	0.40	0.8	—	—	—	2,013	26.7	—	—
	17Mar94	Outlet	27	700	0.60	0.8	—	—	—	2,351	23.5	—	—
	16Mar94	Outlet	32	750	0.24	0.8	—	—	—	2,132	36.9	—	—
	16Mar94	Outlet	37	750	0.40	0.8	—	—	—	2,143	36.6	—	—
	16Mar94	Outlet	42	750	0.60	0.8	—	—	—	2,187	37.9	—	—
	17Mar94	Outlet	22	700	0.40	0.8	—	—	—	—	—	196	—
	19Apr94	Inlet	—	—	—	—	340	—	—	—	—	—	1.8
	19Apr94	Outlet	22	700	0.40	0.8	303	—	—	—	—	—	1.8
F	21Dec93	Outlet	22	700	0.40	0.8	—	—	1.0	—	—	—	—
	04Apr94	Outlet	4	620	0.24	1	—	—	8.1	—	—	—	—
	08Apr94	Outlet	7	620	0.40	0.8	—	—	1.2	—	—	—	—
	14Apr94	Outlet	12	620	0.60	0.8	—	—	4.6	—	—	—	—
	14Apr94	Outlet	14	620	0.60	1.0	—	—	22.9	—	—	—	—
	13Apr94	Outlet	22	700	0.40	0.8	—	—	1.2	—	—	—	—
	13Apr94	Outlet	27	700	0.60	0.8	—	—	2.9	—	—	—	—
	07Apr94	Outlet	42	750	0.60	0.8	—	—	3.7	—	—	—	—
	16Mar94	Outlet	2	620	0.24	0.8	—	—	—	2,165	9.7	—	—
	16Mar94	Outlet	17	700	0.24	0.8	—	—	—	2,190	22.7	—	—
	14Mar94	Outlet	22	700	0.40	0.8	—	—	—	1,961	16.9	—	—
	14Mar94	Outlet	27	700	0.60	0.8	—	—	—	2,028	15.7	—	—

Table A-8 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
F	15Mar94	Outlet	32	750	0.24	0.8	—	—	—	2,015	9.6	—	—
	15Mar94	Outlet	37	750	0.40	0.8	—	—	—	2,040	12	—	—
	15Mar94	Outlet	42	750	0.60	0.8	—	—	—	1,964	13.3	—	—
	16Mar94	Outlet	22	700	0.40	0.8	—	—	—	—	—	140	—
	20Apr94	Inlet	—	—	—	—	310	—	—	—	—	—	2.4
	20Apr94	Outlet	22	700	0.40	0.8	300	—	—	—	—	—	1.6
G	15Apr94	Outlet	7	620	0.40	0.8	—	—	0.9	—	—	—	—
	15Apr94	Outlet	12	620	0.60	0.8	—	—	1.3	—	—	—	—
	19Apr94	Outlet	14	620	0.60	1.0	—	—	18.8	—	—	—	—
	18Apr94	Outlet	22	700	0.40	0.8	—	—	0.9	—	—	—	—
	19Apr94	Outlet	27	700	0.60	0.8	—	—	2.4	—	—	—	—
	18Apr94	Outlet	42	750	0.60	0.8	—	—	2.3	—	—	—	—
	22Mar94	Outlet	2	620	0.24	0.8	—	—	—	2,136	8.6	—	—
	22Mar94	Outlet	17	700	0.24	0.8	—	—	—	2,129	26.1	—	—
	23Mar94	Outlet	22	700	0.40	0.8	—	—	—	2,191	25.6	—	—
	22Mar94	Outlet	27	700	0.60	0.8	—	—	—	2,162	23	—	—
	21Mar94	Outlet	32	750	0.24	0.8	—	—	—	1,969	39.3	—	—
	21Mar94	Outlet	37	750	0.40	0.8	—	—	—	2,013	27.5	—	—
	21Mar94	Outlet	42	750	0.60	0.8	—	—	—	2,096	25.7	—	—
	23Mar94	Outlet	22	700	0.40	0.8	—	—	—	—	—	157	—
	20Apr94	Inlet	—	—	—	—	310	—	—	—	—	—	2.4
	20Apr94	Outlet	22	700	0.40	0.8	319	—	—	—	—	—	1.6

[a] Dash indicates that no tests were performed at these conditions.

Table A-9. Parametric Test Data—Test Sequence 3

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
A	27Jun94	Outlet	2	620	3.0	0.8	383	—[a]	2.3	—	—	—	—
	29Jun94	Outlet	6	620	5.0	0.6	371	123	1.9	—	—	—	—
	29Jun94	Outlet	7	620	5.0	0.8	362	58	2.3	—	—	—	—
	08Aug94	Outlet	9	620	5.0	1.0	292	6	4.5	—	—	—	—
	08Aug94	Outlet	14	620	6.2	1.0	214	3	5.3	—	—	—	—
	24Jun94	Outlet	21	700	5.0	0.6	336	—	1.5	—	—	—	—
	27Jun94	Outlet	22	700	5.0	0.8	363	—	2.5	—	—	—	—
	10Aug94	Outlet	24	700	5.0	1.0	295	33	2.2	—	—	—	—
	28Jun94	Outlet	26	700	6.0	0.6	360	—	2.1	—	—	—	—
	28Jun94	Outlet	27	700	6.0	0.8	331	—	2.7	—	—	—	—
	10Aug94	Outlet	29	700	6.0	1.0	330	32	3.0	—	—	—	—
	09Aug94	Outlet	36	750	5.0	0.6	396	173	2.1	—	—	—	—
	09Aug94	Outlet	37	750	5.0	0.8	390	85	2.0	—	—	—	—
	11Aug94	Outlet	39	750	5.0	1.0	299	42	2.3	—	—	—	—
	14Sep94	Inlet	22	700	5.0	0.8	—	—	—	2,218	0.4	—	—
	14Sep94	Outlet	22	700	5.0	0.8	—	—	—	2,157	18	—	—
	14Sep94	Inlet	37	750	5.0	0.8	—	—	—	2,176	0.2	—	—
	14Sep94	Outlet	37	750	5.0	0.8	—	—	—	2,131	33.8	—	—
	20Sep94	Outlet	22	700	5.0	0.8	—	—	—	—	—	233	—
B	11Jul94	Outlet	2	620	3.0	0.8	339	46	1.6	—	—	—	—
	11Jul94	Outlet	6	620	5.0	0.6	321	109	1	—	—	—	—
	12Jul94	Outlet	7	620	5.0	0.8	317	61	<1.0	—	—	—	—
	13Jul94	Outlet	9	620	5.0	1.0	347	3	3.5	—	—	—	—
	26Aug94	Outlet	14	620	7.5	1.0	357	13	12.3	—	—	—	—
	18Aug94	Outlet	21	700	5.0	0.6	358	134	1.2	—	—	—	—
	13Jul94	Outlet	22	700	5.0	0.8	324	57	1.0	—	—	—	—

Table A-9 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions: Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx	Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2: NH_3	SO_2	SO_3	HCl	N_2O
B	29Aug94	Outlet	24	700	5.0	1.0	344	0.3	3.6	—	—	—	—
	12Aug94	Outlet	26	700	7.5	0.6	342	134	1.2	—	—	—	—
	31Aug94	Outlet	27	700	6.5	0.8	296	51	1.8	—	—	—	—
	26Aug94	Outlet	29	700	7.5	1.0	337	7	5.4	—	—	—	—
	11Aug94	Outlet	36	750	5.0	0.6	284	70	1.2	—	—	—	—
	09Aug94	Outlet	37	750	5.0	0.8	396	83	1.0	—	—	—	—
	09Aug94	Outlet	39	750	5.0	1.0	387	14	2.0	—	—	—	—
	16Sep94	Inlet	22	700	5.0	0.8	—	—	—	2,231	0.1	—	—
	16Sep94	Outlet	22	700	5.0	0.8	—	—	—	2,131	4.9	—	—
	16Sep94	Inlet	37	750	5.0	0.8	—	—	—	2,216	0.2	—	—
	16Sep94	Outlet	37	750	5.0	0.8	—	—	—	2,127	7.2	—	—
	19Sep94	Outlet	22	700	5.0	0.8	—	—	—	—	—	238	—
C	28Jun94	Outlet	2	620	3.0	0.8	347	—	1.0	—	—	—	—
	28Jun94	Outlet	6	620	5.0	0.6	359	—	1.4	—	—	—	—
	29Jun94	Outlet	7	620	5.0	0.8	373	24	3.1	—	—	—	—
	29Jun94	Outlet	9	620	5.0	1.0	365	—	25.3	—	—	—	—
	15Jul94	Outlet	14	620	7.4	1.0	350	22	26.5	—	—	—	—
	24Jun94	Outlet	21	700	5.0	0.6	333	107	1.2	—	—	—	—
	12Jul94	Outlet	22	700	5.0	0.8	378	29	3.6	—	—	—	—
	12Jul94	Outlet	24	700	5.0	1.0	318	6	18.6	—	—	—	—
	13Jul94	Outlet	26	700	6.8	0.6	345	80	4.5	—	—	—	—
	13Jul94	Outlet	27	700	6.8	0.8	323	31	8.5	—	—	—	—
	27Jun94	Outlet	29	700	7.0	1.0	383		19.1	—	—	—	—
	11Jul94	Outlet	36	750	5.0	0.6	337	84	1.6	—	—	—	—
	27Jun94	Outlet	37	750	5.0	0.8	359		3.6	—	—	—	—
	11Jul94	Outlet	39	750	5.0	1.0	321	5	11.3	—	—	—	

Table A-9 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
C	15Sep94	Inlet	22	700	5.0	0.8	—	—	—	2,165	0.2	—	—
	15Sep94	Outlet	22	700	5.0	0.8	—	—	—	2,166	15.3	—	—
	15Sep94	Inlet	37	750	5.0	0.8	—	—	—	2,155	0.2	—	—
	15Sep94	Outlet	37	750	5.0	0.8	—	—	—	2,149	26.9	—	—
	20Sep94	Outlet	22	700	5.0	0.8	—	—	—	—	—	233	—
D	15Jul94	Outlet	2	620	0.24	0.8	350	7	10.1	—	—	—	—
	26Aug94	Outlet	6	620	0.40	0.6	359	33	4.8	—	—	—	—
	25Aug94	Outlet	7	620	0.40	0.8	336	6	15	—	—	—	—
	29Aug94	Outlet	9	620	0.40	1.0	344	11	72.5	—	—	—	—
	29Aug94	Outlet	14	620	0.60	1.0	338	17	73.9	—	—	—	—
	19Aug94	Outlet	21	700	0.40	0.6	313	31	2.6	—	—	—	—
	10Aug94	Outlet	22	700	0.40	0.8	294	6	6.6	—	—	—	—
	10Aug94	Outlet	24	700	0.40	1.0	327	5	38.8	—	—	—	—
	19Aug94	Outlet	26	700	0.60	0.6	358	52	7.4	—	—	—	—
	09Sep94	Outlet	27	700	0.60	0.8	351	18	21.4	—	—	—	—
	09Sep94	Outlet	29	700	0.60	1.0	346	14	57.4	—	—	—	—
	12Sep94	Outlet	36	750	0.40	0.6	291	48	1.8	—	—	—	—
	12Sep94	Outlet	37	750	0.40	0.8	282	30	3.5	—	—	—	—
	13Sep94	Outlet	39	750	0.40	1.0	332	4	14.8	—	—	—	—
	26Sep94	Outlet	2	620	0.40	0.8	364	11	4.5	—	—	—	—
	26Sep94	Outlet	7	620	0.60	0.8	336	23	15.4	—	—	—	—
	27Sep94	Outlet	22	700	0.40	0.8	370	34	4.7	—	—	—	—
	19Sep94	Inlet	22	700	0.40	0.8	—	—	—	2,231	1.3	—	—
	19Sep94	Outlet	22	700	0.40	0.8	—	—	—	2,274	8.9	—	—
	19Sep94	Inlet	37	750	0.40	0.8	—	—	—	2,283	1.9	—	—
	19Sep94	Outlet	37	750	0.40	0.8	—	—	—	2,183	25.1	—	—

Table A-9 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions: Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx	Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2: NH_3	SO_2	SO_3	HCl	N_2O
D	23Sep94	Outlet	22	700	0.40	0.8	—	—	—	—	—	232	—
E	30Aug94	Outlet	2	620	0.24	0.8	322	30	<0.8	—	—	—	—
	30Aug94	Outlet	6	620	0.40	0.6	313	99	<0.8	—	—	—	—
	31Aug94	Outlet	7	620	0.40	0.8	312	72	<0.7	—	—	—	—
	31Aug94	Outlet	9	620	0.40	1.0	314	37	<0.7	—	—	—	—
	02Sep94	Outlet	14	620	0.60	1.0	325	39	26.8	—	—	—	—
	24Aug94	Outlet	21	700	0.40	0.6	348	69	<1.1	—	—	—	—
	23Aug94	Outlet	22	700	0.40	0.8	339	23	<0.9	—	—	—	—
	25Aug94	Outlet	24	700	0.40	1.0	311	2	2.4	—	—	—	—
	29Aug94	Outlet	26	700	0.60	0.6	346	81	<0.8	—	—	—	—
	26Aug94	Outlet	27	700	0.60	0.8	358	26	1.2	—	—	—	—
	25Aug94	Outlet	29	700	0.60	1.0	344	3	11.4	—	—	—	—
	14Sep94	Outlet	36	750	0.40	0.6	323	98	<0.6	—	—	—	—
	14Sep94	Outlet	37	750	0.40	0.8	317	67	0.6	—	—	—	—
	01Sep94	Outlet	39	750	0.40	1.0	334	30	<0.8	—	—	—	—
	20Sep94	Inlet	22	700	0.40	0.8	—	—	—	2,299	1.5	—	—
	20Sep94	Outlet	22	700	0.40	0.8	—	—	—	2,303	9.5	—	—
	20Sep94	Inlet	37	750	0.40	0.8	—	—	—	2,315	0.4	—	—
	20Sep94	Outlet	37	750	0.40	0.8	—	—	—	2,276	15	—	—
	23Sep94	Outlet	22	700	0.40	0.8	—	—	—	—	—	226	—
F	15Jul94	Outlet	2	620	0.24	0.8	352	25	1.7	—	—	—	—
	02Sep94	Outlet	6	620	0.40	0.6	318	68	0.9	—	—	—	—
	02Sep94	Outlet	7	620	0.40	0.8	311	18	3.2	—	—	—	—
	22Aug94	Outlet	9	620	0.40	1.0	330	3	78.7	—	—	—	—
	23Aug94	Outlet	14	620	0.60	1.0	348	11	90.1	—	—	—	—
	18Aug94	Outlet	21	700	0.40	0.6	359	57	2.2	—	—	—	—

Table A-9 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
F	01Sep94	Outlet	22	700	0.40	0.8	327	52	1.0	—	—	—	—
	01Sep94	Outlet	24	700	0.40	1.0	350	2	17.3	—	—	—	—
	19Aug94	Outlet	26	700	0.60	0.6	315	64	3.8	—	—	—	—
	13Sep94	Outlet	27	700	0.60	0.8	336	34	9.3	—	—	—	—
	13Sep94	Outlet	29	700	0.60	1.0	329	11	56.5	—	—	—	—
	18Aug94	Outlet	36	750	0.40	0.6	357	80	2.8	—	—	—	—
	12Aug94	Outlet	37	750	0.40	58.0	252	11	3.1	—	—	—	—
	12Aug94	Outlet	39	750	0.40	1.0	341	1	52.7	—	—	—	—
	24Aug94	Outlet	2	620	0.24	0.8	342	0	41.1	—	—	—	—
	19Aug94	Outlet	21	700	0.40	0.6	359	67	<0.9	—	—	—	—
	12Sep94	Outlet	39	750	0.40	1	287	2	18.4	—	—	—	—
	21Sep94	Inlet	22	700	0.40	0.8	—	—	—	2,160	0.2	—	—
	21Sep94	Outlet	22	700	0.40	0.8	—	—	—	2,187	1.7	—	—
	21Sep94	Inlet	37	750	0.40	0.8	—	—	—	2,167	1.0	—	—
	21Sep94	Outlet	37	750	0.40	0.8	—	—	—	2,168	3.4	—	—
	20Sep94	Outlet	22	700	0.40	0.8	—	—	—	—	—	241	—
G	23Aug94	Outlet	2	620	0.24	0.8	347	17	<1.0	—	—	—	—
	23Aug94	Outlet	6	620	0.40	0.6	349	81	<0.9	—	—	—	—
	24Aug94	Outlet	7	620	0.40	0.8	342	14	2.2	—	—	—	—
	08Sep94	Outlet	9	620	0.40	1.0	367	0	94.1	—	—	—	—
	14Sep94	Outlet	14	620	0.60	1.0	312	21	43.8	—	—	—	—
	09Sep94	Outlet	21	700	0.40	0.6	352	78	0.8	—	—	—	—
	09Sep94	Outlet	22	700	0.40	0.8	348	19	2.2	—	—	—	—
	19Aug94	Outlet	24	700	0.40	1.0	358	1	57.3	—	—	—	—
	12Sep94	Outlet	26	700	0.60	0.6	289	107	1.3	—	—	—	—
	12Sep94	Outlet	27	700	0.60	0.8	281	62	3.1	—	—	—	—

Table A-9 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
G	19Aug94	Outlet	29	700	0.60	1.0	314	3	41.6	—	—	—	—
	13Sep94	Outlet	36	750	0.40	0.6	336	102	1.3	—	—	—	—
	13Sep94	Outlet	37	750	0.40	0.8	328	72	2.2	—	—	—	—
	22Aug94	Outlet	39	750	0.40	1.0	331	8	32.7	—	—	—	—
	22Sep94	Inlet	22	700	0.40	0.8	—	—	—	2,286	0.5	—	—
	22Sep94	Outlet	22	700	0.40	0.8	—	—	—	2,172	2.2	—	—
	22Sep94	Inlet	37	750	0.40	0.8	—	—	—	2,197	0.4	—	—
	22Sep94	Outlet	37	750	0.40	0.8	—	—	—	1,948	17.1	—	—
	21Sep94	Outlet	22	700	0.40	0.8	—	—	—	—	—	225	—
J	24Aug94	Outlet	2	620	0.24	0.8	307	119	1.2	—	—	—	—
	25Aug94	Outlet	6	620	0.40	0.6	323	144	1.9	—	—	—	—
	25Aug94	Outlet	7	620	0.40	0.8	304	109	3.0	—	—	—	—
	26Aug94	Outlet	9	620	0.40	1.0	331	84	5.1	—	—	—	—
	26Aug94	Outlet	14	620	0.60	1.0	321	87	21.8	—	—	—	—
	30Aug94	Outlet	21	700	0.40	0.6	299	126	0.8	—	—	—	—
	01Sep94	Outlet	22	700	0.40	0.8	306	109	1.3	—	—	—	—
	01Sep94	Outlet	24	700	0.40	1.0	321	16	4.1	—	—	—	—
	30Aug94	Outlet	26	700	0.60	0.6	300	122	2.0	—	—	—	—
	31Aug94	Outlet	27	700	0.60	0.8	293	73	3.9	—	—	—	—
	31Aug94	Outlet	29	700	0.60	1.0	292	31	8.9	—	—	—	—
	23Sep94	Inlet	22	700	0.40	0.8	—	—	—	2,160	0.5	—	—
	23Sep94	Outlet	22	700	0.40	0.8	—	—	—	2,376	9.1	—	—
	21Sep94	Outlet	22	700	0.40	0.8	—	—	—	—	—	234	—

[a] Dash indicates that no tests were performed at these conditions.

Table A-10. Parametric Test Data—Test Sequence 4

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
A	25Oct94	Outlet	2	620	3.0	0.8	289	44	2.1	—[a]	—	—	—
	27Oct94	Outlet	6	620	5.0	0.6	378	73	3.0	—	—	—	—
	27Oct94	Outlet	7	620	5.0	0.8	360	50	4.9	—	—	—	—
	01Nov94	Outlet	9	620	5.0	1.0	377	38	25.0	—	—	—	—
	25Oct94	Outlet	14	620	6.8	1.0	302	38	7.2	—	—	—	—
	28Oct94	Outlet	21	700	5.0	0.6	376	71	2.8	—	—	—	—
	24Oct94	Outlet	22	700	5.0	0.8	268	64	3.3	—	—	—	—
	28Oct94	Outlet	24	700	5.0	1.0	365	63	2.8	—	—	—	—
	26Oct94	Outlet	26	700	6.4	0.6	343	100	3.3	—	—	—	—
	24Oct94	Outlet	27	700	6.0	0.8	263	64	3.0	—	—	—	—
	26Oct94	Outlet	29	700	6.4	1.0	320	13	10.2	—	—	—	—
	31Oct94	Outlet	36	750	5.0	0.6	357	105	2.1	—	—	—	—
	31Oct94	Outlet	37	750	5.0	0.8	313	39	3.1	—	—	—	—
	02Nov94	Outlet	39	750	5.0	1.0	337	8	8.3	—	—	—	—
	01Dec94	Inlet	22	700	5.0	0.8	—	—	—	1,913	10.0	—	—
	01Dec94	Outlet	22	700	5.0	0.8	—	—	—	1,825	20.0	—	—
	12Jan95	Inlet	27	700	6.4	0.8	—	—	—	1,857	5.0	—	—
	12Jan95	Outlet	27	700	6.4	0.8	—	—	—	1,799	16.6	—	—
	01Dec94	Inlet	37	750	5.0	0.8	—	—	—	1,894	10.6	—	—
	01Dec94	Outlet	37	750	5.0	0.8	—	—	—	1,860	45.3	—	—
	01Dec94	Inlet	22	700	5.0	0.8	—	—	—	—	—	139	—
	01Dec94	Outlet	22	700	5.0	0.8	—	—	—	—	—	219	—
	04Jan94	Inlet	22	700	5.0	0.8	—	—	—	—	—	—	1.2
	04Jan94	Outlet	22	700	5.0	0.8	—	—	—	—	—	—	1.3

Table A-10 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
B	25Oct94	Outlet	2	620	3.0	0.8	303	61	1.1	—	—	—	—
	26Oct94	Outlet	6	620	5.0	0.6	328	98	<0.7	—	—	—	—
	27Oct94	Outlet	7	620	5.0	0.8	374	18	1.6	—	—	—	—
	27Oct94	Outlet	9	620	5.0	1.0	361	3	11.5	—	—	—	—
	01Nov94	Outlet	14	620	7.3	1.0	383	8	25.9	—	—	—	—
	03Nov94	Outlet	21	700	5.0	0.6	335	108	<1.1	—	—	—	—
	26Oct94	Outlet	22	700	5.0	0.8	305	37	1.2	—	—	—	—
	28Oct94	Outlet	24	700	5.0	1.0	376	0	11.2	—	—	—	—
	28Oct94	Outlet	26	700	7.5	0.6	377	100	1.5	—	—	—	—
	24Oct94	Outlet	27	700	6.8	0.8	266	85	2.3	—	—	—	—
	31Oct94	Outlet	29	700	6.6	1.0	338	6	6.7	—	—	—	—
	31Oct94	Outlet	36	750	5.0	0.6	334	109	1.1	—	—	—	—
	02Nov94	Outlet	37	750	5.0	0.8	339	42	1.2	—	—	—	—
	02Nov94	Outlet	39	750	5.0	1.0	322	9	2.3	—	—	—	—
	30Nov94	Inlet	22	700	5.0	0.8	—	—	—	2,161	6.6	—	—
	30Nov94	Outlet	22	700	5.0	0.8	—	—	—	2,112	4.6	—	—
	12Jan95	Inlet	27	700	6.3	0.8	—	—	—	1,821	2.0	—	—
	12Jan95	Outlet	27	700	6.3	0.8	—	—	—	1,787	2.9	—	—
	30Nov94	Inlet	37	750	5.0	0.8	—	—	—	1,934	9.7	—	—
	30Nov94	Outlet	37	750	5.0	0.8	—	—	—	2,013	18.9	—	—
	30Nov94	Inlet	22	700	5.0	0.8	—	—	—	—	—	161	—
	30Nov94	Outlet	22	700	5.0	0.8	—	—	—	—	—	222	—
	04Jan95	Inlet	22	700	5.0	0.8	361	—	—	—	—	—	1.2
	04Jan95	Outlet	22	700	5.0	0.8	365	—	—	—	—	—	1.3

Table A-10 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
C	28Oct94	Outlet	2	620	3.0	0.8	377	3	2.7	—	—	—	—
	28Oct94	Outlet	6	620	5.0	0.6	376	59	2.8	—	—	—	—
	31Oct94	Outlet	7	620	5.0	0.8	358	13	7.1	—	—	—	—
	31Oct94	Outlet	9	620	5.0	1.0	330	2	42.2	—	—	—	—
	09Nov94	Outlet	14	620	6.5	1.0	361		45.6	—	—	—	—
	01Nov94	Outlet	21	700	5.0	0.6	379	95	3.3	—	—	—	—
	02Nov94	Outlet	22	700	5.0	0.8	346	45	5.7	—	—	—	—
	02Nov94	Outlet	24	700	5.0	1.0	307	6	17	—	—	—	—
	03Nov94	Outlet	26	700	6.4	0.6	336	129	5.1	—	—	—	—
	03Nov94	Outlet	27	700	6.4	0.8	326	34	9.4	—	—	—	—
	08Nov94	Outlet	29	700	6.3	1.0	373	0	22	—	—	—	—
	08Nov94	Outlet	36	750	5.0	0.6	362		2.8	—	—	—	—
	04Nov94	Outlet	37	750	5.0	0.8	326	4	4.8	—	—	—	—
	04Nov94	Outlet	39	750	5.0	1.0	339	11	17.7	—	—	—	—
	28Nov94	Inlet	22	700	5.0	0.8	—	—	—	2,101	9.6	—	—
	28Nov94	Outlet	22	700	5.0	0.8	—	—	—	2,181	14.1	—	—
	16Jan95	Inlet	27	700	6.0	0.8	—	—	—	1,864	6.0	—	—
	16Jan95	Outlet	27	700	6.0	0.8	—	—	—	1,791	2.7	—	—
	28Nov94	Inlet	37	750	5.0	0.8	—	—	—	2,127	11.9	—	—
	28Nov94	Outlet	37	750	5.0	0.8	—	—	—	2,152	40.9	—	—
	28Nov94	Inlet	22	700	5.0	0.8	—	—	—	—	—	195	—
	28Nov94	Outlet	22	700	5.0	0.8	—	—	—	—	—	260	—
	05Jan95	Inlet	—	—	—	—	345	—	—	—	—	—	1.2
	05Jan95	Outlet	22	700	5.0	0.8	349	50	—	—	—	—	2.0

Table A-10 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
D	04Jan95	Outlet	2	620	0.24	0.8	353	16	5.8	—	—	—	—
	04Jan95	Outlet	6	620	0.40	0.6	350	60	8.5	—	—	—	—
	04Jan95	Outlet	7	620	0.40	0.8	359	42	24.4	—	—	—	—
	11Jan95	Outlet	9	620	0.40	1.0	361	26	78.8	—	—	—	—
	11Jan95	Outlet	14	620	0.60	1.0	384	60	94.1	—	—	—	—
	05Jan95	Outlet	21	700	0.40	0.6	345	79	2.2	—	—	—	—
	05Jan95	Outlet	22	700	0.40	0.8	345	23	7.5	—	—	—	—
	05Jan95	Outlet	24	700	0.40	1.0	345	14	30.5	—	—	—	—
	09Jan95	Outlet	26	700	0.60	0.6	343	58	3.2	—	—	—	—
	09Jan95	Outlet	27	700	0.60	0.8	345	18	10.4	—	—	—	—
	09Jan95	Outlet	29	700	0.60	1.0	338	9	40.1	—	—	—	—
	10Jan95	Outlet	36	750	0.40	0.6	357	63	2.9	—	—	—	—
	10Jan95	Outlet	37	750	0.40	0.8	356	26	7.2	—	—	—	—
	10Jan95	Outlet	39	750	0.40	1.0	351	8	29.9	—	—	—	—
	05Dec94	Inlet	22	700	0.40	0.8	—	—	—	1,813	4.9	—	—
	05Dec94	Outlet	22	700	0.40	0.8	—	—	—	1,839	14.6	—	—
	17Jan95	Inlet	27	700	0.60	0.8	—	—	—	1,801	0.8	—	—
	17Jan95	Outlet	27	700	0.60	0.8	—	—	—	1,726	0.2	—	—
	06Dec94	Inlet	37	750	0.40	0.8	—	—	—	1,829	1.2	—	—
	06Dec94	Outlet	37	750	0.40	0.8	—	—	—	1,834	12.0	—	—
	05Dec94	Inlet	22	700	0.40	0.8	—	—	—	—	—	164	—
	05Dec94	Outlet	22	700	0.40	0.8	—	—	—	—	—	223	—
	05Jan95	Inlet	—	—	—	—	345	—	—	—	—	—	1.2
	05Jan95	Outlet	22	700	0.40	0.8	345	—	—	—	—	—	2.0

Table A-10 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
E	14Nov94	Outlet	2	620	0.24	0.8	402	68	<0.9	—	—	—	—
	04Nov94	Outlet	6	620	0.40	0.6	337	139	<0.8	—	—	—	—
	04Nov94	Outlet	7	620	0.40	0.8	312	50	<0.8	—	—	—	—
	15Nov94	Outlet	9	620	0.40	1.0	374	3	13.5	—	—	—	—
	15Nov94	Outlet	14	620	0.60	1.0	384	8	61.9	—	—	—	—
	11Nov94	Outlet	21	700	0.40	0.6	363	38	<0.8	—	—	—	—
	11Nov94	Outlet	22	700	0.40	0.8	375	35	<0.8	—	—	—	—
	10Nov94	Outlet	24	700	0.40	1.0	362	2	1.6	—	—	—	—
	10Nov94	Outlet	26	700	0.60	0.6	347	57	1.1	—	—	—	—
	08Nov94	Outlet	27	700	0.60	0.8	380	36	1.9	—	—	—	—
	08Nov94	Outlet	29	700	0.60	1.0	362	6	6.1	—	—	—	—
	16Nov94	Outlet	36	750	0.40	0.6	342	73	<0.9	—	—	—	—
	09Nov94	Outlet	37	750	0.40	0.8	364	28	<0.8	—	—	—	—
	09Nov94	Outlet	39	750	0.40	1.0	365	3	<0.8	—	—	—	—
	14Nov94	Outlet	2	620	0.24	0.8	360	72	<0.9	—	—	—	—
	06Dec94	Inlet	22	700	0.40	0.8	—	—	—	1,898	3.0	—	—
	06Dec94	Outlet	22	700	0.40	0.8	—	—	—	1,888	10.1	—	—
	17Jan95	Inlet	27	700	0.60	0.8	—	—	—	1,870	0.3	—	—
	17Jan95	Outlet	27	700	0.60	0.8	—	—	—	1,890	6.6	—	—
	06Dec94	Inlet	37	750	0.40	0.8	—	—	—	1,872	1.3	—	—
	06Dec94	Outlet	37	750	0.40	0.8	—	—	—	1,864	11.7	—	—
	06Dec94	Inlet	22	700	0.40	0.8	—	—	—	—	—	176	—
	06Dec94	Outlet	22	700	0.40	0.8	—	—	—	—	—	233	—
	05Jan95	Inlet	—	—	—	—	345	—	—	—	—	—	1.2
	05Jan95	Outlet	22	700	0.40	0.8	345	44	—	—	—	—	1.8

Table A-10 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
F	15Nov94	Outlet	2	620	0.24	0.8	385	19	<0.9	—	—	—	—
	14Nov94	Outlet	6	620	0.40	0.6	378	64	1.3	—	—	—	—
	14Nov94	Outlet	7	620	0.40	0.8	396	32	3.1	—	—	—	—
	15Nov94	Outlet	9	620	0.40	1.0	383	7	12.2	—	—	—	—
	03Nov94	Outlet	14	620	0.60	1.0	325	18	32.8	—	—	—	—
	08Nov94	Outlet	21	700	0.40	0.6	374	94	<0.8	—	—	—	—
	08Nov94	Outlet	22	700	0.40	0.8	362	59	1.0	—	—	—	—
	10Nov94	Outlet	24	700	0.40	1.0	341	4	12.5	—	—	—	—
	04Nov94	Outlet	26	700	0.60	0.6	327	94	2.9	—	—	—	—
	04Nov94	Outlet	27	700	0.60	0.8	313	52	4.6	—	—	—	—
	16Nov94	Outlet	29	700	0.60	1.0	338	13	24.5	—	—	—	—
	11Nov94	Outlet	36	750	0.40	0.6	367	72	1.1	—	—	—	—
	09Nov94	Outlet	37	750	0.40	0.8	348	57	1.0	—	—	—	—
	16Nov94	Outlet	39	750	0.40	1.0	340	7	2.9	—	—	—	—
	10Nov94	Outlet	26	620	0.60	0.6	363	109	3.4	—	—	—	—
	07Dec94	Inlet	22	700	0.40	0.8	—	—	—	1,935	0.8	—	—
	07Dec94	Outlet	22	700	0.40	0.8	—	—	—	1,942	1.1	—	—
	18Jan95	Inlet	27	700	0.60	0.8	—	—	—	1,884	1.4	—	—
	18Jan95	Outlet	27	700	0.60	0.8	—	—	—	1,798	0.2	—	—
	07Dec94	Inlet	37	750	0.40	0.8	—	—	—	1,907	0.7	—	—
	07Dec94	Outlet	37	750	0.40	0.8	—	—	—	1,900	0.8	—	—
	07Dec94	Inlet	22	700	0.40	0.8	—	—	—	—	—	174	—
	07Dec94	Outlet	22	700	0.40	0.8	—	—	—	—	—	250	—
	05Jan95	Inlet	—	—	—	—	345	—	—	—	—	—	1.2
	05Jan95	Outlet	22	700	0.40	0.8	345	35	—	—	—	—	2.0

Table A-10 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
G	25Oct94	Outlet	2	620	0.24	0.8	302	61	<0.8	—	—	—	—
	25Oct94	Outlet	6	620	0.40	0.6	302	103	<0.7	—	—	—	—
	26Oct94	Outlet	7	620	0.40	0.8	330	36	3.2	—	—	—	—
	26Oct94	Outlet	9	620	0.40	1.0	319	73	19.4	—	—	—	—
	24Oct94	Outlet	14	620	0.60	1.0	267	37	13.0	—	—	—	—
	02Nov94	Outlet	21	700	0.40	0.6	321	96	0.9	—	—	—	—
	03Nov94	Outlet	22	700	0.40	0.8	336	35	2.0	—	—	—	—
	03Nov94	Outlet	24	700	0.40	1.0	326	22	10.6	—	—	—	—
	27Oct94	Outlet	26	700	0.60	0.6	374	98	3.6	—	—	—	—
	27Oct94	Outlet	27	700	0.60	0.8	362	60	6.0	—	—	—	—
	08Nov94	Outlet	29	700	0.60	1.0	377	43	16.3	—	—	—	—
	04Nov94	Outlet	36	750	0.40	0.6	312	101	1.4	—	—	—	—
	04Nov94	Outlet	37	750	0.40	0.8	315	67	3.2	—	—	—	—
	28Oct94	Outlet	39	750	0.40	1.0	377	18	9.0	—	—	—	—
	08Dec94	Inlet	22	700	0.40	0.8	—	—	—	1,803	0.4	—	—
	08Dec94	Outlet	22	700	0.40	0.8	—	—	—	2,008	3.8	—	—
	08Dec94	Inlet	27	700	0.60	0.8	—	—	—	1,833	2.2	—	—
	08Dec94	Outlet	27	700	0.60	0.8	—	—	—	1,804	4.3	—	—
	16Jan95	Inlet	37	750	0.40	0.8	—	—	—	1,999	0.6		—
	16Jan95	Outlet	37	750	0.40	0.8	—	—	—	1,940	14.8	—	—
	08Dec94	Inlet	22	700	0.40	0.8	—	—	—	—	—	189	—
	08Dec94	Outlet	22	700	0.40	0.8	—	—	—	—	—	256	—
	05Jan95	Inlet	22	700	0.40	0.8	345	—	—	—	—	—	1.2
	05Jan95	Outlet	22	700	0.40	0.8	345	52	—	—	—	—	2.3

Table A-10 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
J	26Oct94	Outlet	2	620	0.24	0.8	294	87	1.2	—	—	—	—
	26Oct94	Outlet	6	620	0.40	0.6	313	137	0.8	—	—	—	—
	27Oct94	Outlet	7	620	0.40	0.8	332	53	1.8	—	—	—	—
	27Oct94	Outlet	9	620	0.40	1.0	323	11	7.8	—	—	—	—
	25Oct94	Outlet	14	620	0.60	1.0	308	46	20.3	—	—	—	—
	02Nov94	Outlet	21	700	0.40	0.6	310	119	0.7	—	—	—	—
	02Nov94	Outlet	22	700	0.40	0.8	300	56	1.1	—	—	—	—
	03Nov94	Outlet	24	700	0.40	1.0	305	23	2.1	—	—	—	—
	03Nov94	Outlet	26	700	0.60	0.6	297	113	1.5	—	—	—	—
	31Oct94	Outlet	27	700	0.60	0.8	321	59	4.8	—	—	—	—
	31Oct94	Outlet	29	700	0.60	1.0	299	20	24.4	—	—	—	—
	09Jan95	Outlet	36	750	0.40	0.6	224	60	2.8	—	—	—	—
	11Jan95	Outlet	37	750	0.40	0.8	261	37	4.6	—	—	—	—
	09Jan95	Outlet	39	750	0.40	1.0	227	8	11.1	—	—	—	—
	09Dec94	Inlet	22	700	0.40	0.8	—	—	—	2,033	0.7	—	—
	09Dec94	Outlet	22	700	0.40	0.8	—	—	—	2,030	3.7	—	—
	12Dec94	Inlet	27	700	0.60	0.8	—	—	—	2,050	1.6	—	—
	12Dec94	Outlet	27	700	0.60	0.8	—	—	—	2,078	7.6	—	—
	09Dec94	Inlet	37	750	0.40	0.8	—	—	—	1,952	1.0	—	—
	09Dec94	Outlet	37	750	0.40	0.8	—	—	—	1,997	12.7	—	—
	09Dec94	Inlet	22	700	0.40	0.8	—	—	—	—	—	179	—
	09Dec94	Outlet	22	700	0.40	0.8	—	—	—	—	—	244	—
	04Jan95	Inlet	22	700	0.40	0.8	361	—	—	—	—	—	1.2
	04Jan95	Outlet	22	700	0.40	0.8	360	50	—	—	—	—	2.5

[a] Dash indicates that no tests were performed at these conditions.

Table A-11. Parametric Test Data—Test Sequence 5

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
A	08Jun95	Outlet	2	620	3.0	0.8	347	92	<0.8	—[a]	—	—	—
	07Jun95	Outlet	6	620	5.0	0.6	367	125	<0.8	—	—	—	—
	07Jun95	Outlet	7	620	5.0	0.8	360	60	<0.7	—	—	—	—
	05Jul95	Outlet	9	620	5.0	1.0	338	19	1.6	—	—	—	—
	07Jul95	Outlet	14	620	6.8	1.0	338	56	2.7	—	—	—	—
	05Jun95	Outlet	21	700	5.0	0.6	308	117	<0.9	—	—	—	—
	04Jun95	Outlet	22	700	5.0	0.8	357	52	4.3	—	—	—	—
	06Jul95	Outlet	24	700	5.0	1.0	335	18	<0.9	—	—	—	—
	06Jun95	Outlet	26	700	6.4	0.6	325	134	<0.7	—	—	—	—
	05Jun95	Outlet	27	700	6.0	0.8	249	84	<0.8	—	—	—	—
	10Jul95	Outlet	29	700	6.4	1.0	336	45	1.6	—	—	—	—
	14Jun95	Outlet	36	750	5.0	0.6	365	152	<0.8	—	—	—	—
	14Jun95	Outlet	37	750	5.0	0.8	369	99	<0.9	—	—	—	—
	06Jul95	Outlet	39	750	5.0	1.0	321	39	1.6	—	—	—	—
	01Jun95	Inlet	22	700	5.0	0.8	—	—	—	1,564	1.0	—	—
	01Jun95	Outlet	22	700	5.0	0.8	—	—	—	1,534	7.7	—	—
	03Jul95	Inlet	22	700	5.0	0.8	—	—	—	—	—	132	—
	03Jul95	Outlet	22	700	5.0	0.8	—	—	—	—	—	86	—
	16Jun95	Inlet	22	700	5.0	0.8	—	—	—	—	—	—	2.0
	16Jun95	Outlet	22	700	5.0	0.8	—	—	—	—	—	—	1.6
B	06Jun95	Outlet	2	620	3.0	0.8	348	48	<0.9	—	—	—	—
	07Jun95	Outlet	6	620	5.0	0.6	363	110	<0.8	—	—	—	—
	07Jun95	Outlet	7	620	5.0	0.8	356	50	<0.8	—	—	—	—
	07Jun95	Outlet	9	620	5.0	1.0	338	2	2.4	—	—	—	—

Table A-11 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
B	07Jun95	Outlet	14	620	7.3	1.0	344	6	5.9	—	—	—	—
	05Jun95	Outlet	21	700	5.0	0.6	256	60	<0.9	—	—	—	—
	04Jun95	Outlet	22	700	5.0	0.8	353	45	<0.9	—	—	—	—
	12Jun95	Outlet	22	700	5.0	0.8	366	31	<0.7	—	—	—	—
	06Jul95	Outlet	24	700	5.0	1.0	336	2	1.3	—	—	—	—
	06Jun95	Outlet	26	700	7.5	0.6	347	117	<0.8	—	—	—	—
	05Jun95	Outlet	27	700	6.8	0.8	340	65	<0.9	—	—	—	—
	08Jul95	Outlet	29	700	6.6	1.0	349	28	2.6	—	—	—	—
	09Jun95	Outlet	36	750	5.0	0.6	350	123	<0.6	—	—	—	—
	14Jun95	Outlet	37	750	5.0	0.8	365	61	<0.8	—	—	—	—
	05Jul95	Outlet	39	750	5.0	1.0	325	7	1.6	—	—	—	—
	01Jul95	Inlet	22	700	5.0	0.8	—	—	—	1,499	0.4	—	—
	01Jul95	Outlet	22	700	5.0	0.8	—	—	—	1,464	0.6	—	—
	16Jun95	Inlet	22	700	5.0	0.8	—	—	—	—	—	—	2.0
	16Jun95	Outlet	22	700	5.0	0.8	—	—	—	—	—	—	1.6
C	14Jun95	Outlet	2	620	3.0	0.8	364	46	<0.9	—	—	—	—
	12Jun95	Outlet	6	620	5.0	0.6	384	73	3.4	—	—	—	—
	12Jun95	Outlet	7	620	5.0	0.8	382	15	13.5	—	—	—	—
	12Jun95	Outlet	9	620	5.0	1.0	325	4	46.4	—	—	—	—
	12Jul95	Outlet	14	620	6.5	1.0	342	6	46.9	—	—	—	—
	10Jun95	Outlet	21	700	5.0	0.6	337	105	2.4	—	—	—	—
	10Jun95	Outlet	22	700	5.0	0.8	336	43	5.5	—	—	—	—
	13Jul95	Outlet	24	700	5.0	1.0	332	4	27.2	—	—	—	—
	10Jun95	Outlet	26	700	6.4	0.6	338	101	6.5	—	—	—	—
	13Jun95	Outlet	27	700	6.4	0.8	383	43	14	—	—	—	—

Table A-11 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
C	08Jul95	Outlet	29	700	6.3	1.0	353	6	34.7	—	—	—	—
	13Jun95	Outlet	36	750	5.0	0.6	387	113	3.2	—	—	—	—
	13Jun95	Outlet	37	750	5.0	0.8	386	57	6.4	—	—	—	—
	11Jul95	Outlet	39	750	5.0	1.0	317	15	10.9	—	—	—	—
	01Jul95	Inlet	22	700	5.0	0.8	—	—	—	1,547	1.2	—	—
	01Jul95	Outlet	22	700	5.0	0.8	—	—	—	1,488	8.8	—	—
	16Jun95	Inlet	22	700	5.0	0.8	—	—	—	—	—	—	2.0
	16Jun95	Outlet	22	700	5.0	0.8	—	—	—	—	—	—	2.5
D	06Jun95	Outlet	2	620	0.24	0.8	327	12	1.0	—	—	—	—
	07Jun95	Outlet	6	620	0.40	0.6	368	73	2.0	—	—	—	—
	06Jun95	Outlet	7	620	0.40	0.8	346	51	5.5	—	—	—	—
	05Jul95	Outlet	9	620	0.40	1.0	338	46	13.2	—	—	—	—
	07Jul95	Outlet	14	620	0.60	1.0	339	77	35.7	—	—	—	—
	05Jun95	Outlet	21	700	0.40	0.6	251	48	1.7	—	—	—	—
	04Jun94	Outlet	22	700	0.40	0.8	357	46	3.4	—	—	—	—
	06Jul95	Outlet	24	700	0.40	1.0	334	34	4.8	—	—	—	—
	07Jun95	Outlet	26	700	0.60	0.6	353	87	4.5	—	—	—	—
	09Jun95	Outlet	27	700	0.60	0.8	350	73	9.7	—	—	—	—
	08Jul95	Outlet	29	700	0.60	1.0	350	56	19.3	—	—	—	—
	13Jun95	Outlet	36	750	0.40	0.6	386	89	1.6	—	—	—	—
	13Jun95	Outlet	37	750	0.40	0.8	387	62	2.7	—	—	—	—
	06Jul95	Outlet	39	750	0.40	1.0	323	41	4.7	—	—	—	—
	02Jun95	Inlet	22	700	0.40	0.8	—	—	—	1,669	4.2	—	—
	02Jun95	Outlet	22	700	0.40	0.8	—	—	—	1,683	1.3	—	—
	16Jun95	Inlet	22	700	0.40	0.8	—	—	—	—	—	—	2.0

Table A-11 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
D	16Jun95	Outlet	22	700	0.40	0.8	—	—	—	—	—	—	2.1
E	08Jun95	Outlet	2	620	0.24	0.8	348	117	<0.7	—	—	—	—
	07Jun95	Outlet	6	620	0.40	0.6	361	149	<0.8	—	—	—	—
	07Jun95	Outlet	7	620	0.40	0.8	357	118	<0.8	—	—	—	—
	07Jul95	Outlet	9	620	0.40	1.0	338	84	0.9	—	—	—	—
	07Jul95	Outlet	14	620	0.60	1.0	344	56	3.6	—	—	—	—
	05Jun95	Outlet	21	700	0.40	0.6	257	122	<0.7	—	—	—	—
	04Jun95	Outlet	22	700	0.40	0.8	356	108	1.0	—	—	—	—
	06Jul95	Outlet	24	700	0.40	1.0	336	57	<0.8	—	—	—	—
	06Jun95	Outlet	26	700	0.60	0.6	349	157	0.8	—	—	—	—
	05Jun95	Outlet	27	700	0.60	0.8	340	103	1.0	—	—	—	—
	08Jul95	Outlet	29	700	0.60	1.0	352	66	2.6	—	—	—	—
	15Jun95	Outlet	36	750	0.40	0.6	377	121	<0.7	—	—	—	—
	15Jun95	Outlet	37	750	0.40	0.8	388	63	<0.7	—	—	—	—
	05Jul95	Outlet	39	750	0.40	1.0	325	73	<0.7	—	—	—	—
	02Jun95	Inlet	22	700	0.40	0.8	—	—	—	1,666	4.9	—	—
	02Jun95	Outlet	22	700	0.40	0.8	—	—	—	1,691	5.4	—	—
	16Jun95	Inlet	22	700	0.40	0.8	—	—	—	—	—	—	2.0
	16Jun95	Outlet	22	700	0.40	0.8	—	—	—	—	—	—	1.8
F	15Jun95	Outlet	2	620	0.24	0.8	386	15	<0.7	—	—	—	—
	08Jun95	Outlet	6	620	0.40	0.6	348	117	0.9	—	—	—	—
	08Jun95	Outlet	7	620	0.40	0.8	349	85	1.6	—	—	—	—
	12Jul95	Outlet	9	620	0.40	1.0	328	69	2.0	—	—	—	—
	10Jul95	Outlet	14	620	0.60	1.0	331	65	12.4	—	—	—	—
	12Jun95	Outlet	21	700	0.40	0.6	383	116	1.3	—	—	—	—

Table A-11 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
F	04Jun95	Outlet	22	700	0.40	0.8	340	65	1.6	—	—	—	—
	11Jul95	Outlet	24	700	0.40	1.0	312	72	1.2	—	—	—	—
	10Jun95	Outlet	26	700	0.60	0.6	337	132	2.8	—	—	—	—
	10Jun95	Outlet	27	700	0.60	0.8	339	103	4.6	—	—	—	—
	11Jul95	Outlet	29	700	0.60	1.0	322	77	5.2	—	—	—	—
	09Jun95	Outlet	36	750	0.40	0.6	342	127	1.3	—	—	—	—
	09Jun95	Outlet	37	750	0.40	0.8	348	103	1.5	—	—	—	—
	10Jul95	Outlet	39	750	0.40	1.0	343	68	1.8	—	—	—	—
	03Jun95	Inlet	22	700	0.40	0.8	—	—	—	1,754	4.8	—	—
	03Jun95	Outlet	22	700	0.40	0.8	—	—	—	1,736	1.2	—	—
	16Jun95	Inlet	22	700	0.40	0.8	—	—	—	—	—	—	2.0
	16Jun95	Outlet	22	700	0.40	0.8	—	—	—	—	—	—	2.2
G	13Jun95	Outlet	2	620	0.24	0.8	384	105	<0.7	—	—	—	—
	09Jun95	Outlet	6	620	0.40	0.6	342	150	<0.7	—	—	—	—
	09Jun95	Outlet	7	620	0.40	0.8	348	114	0.8	—	—	—	—
	10Jul95	Outlet	9	620	0.40	1.0	336	83	2.6	—	—	—	—
	10Jul95	Outlet	14	620	0.60	1.0	331	80	6.8	—	—	—	—
	08Jun95	Outlet	21	700	0.40	0.6	350	157	<0.6	—	—	—	—
	08Jun95	Outlet	22	700	0.40	0.8	348	128	0.8	—	—	—	—
	12Jul95	Outlet	24	700	0.40	1.0	342	123	2.4	—	—	—	—
	12Jun95	Outlet	26	700	0.60	0.6	369	151	2.6	—	—	—	—
	12Jun95	Outlet	27	700	0.60	0.8	384	112	5.9	—	—	—	—
	13Jul95	Outlet	29	700	0.60	1.0	342	73	6.5	—	—	—	—
	14Jun95	Outlet	36	750	0.40	0.6	369	164	<0.7	—	—	—	—
	14Jun95	Outlet	37	750	0.40	0.8	366	127	1.0	—	—	—	—

Table A-11 (continued)

Reactor	Date	Location	Target Reactor Operating Conditions				Inlet NOx, wppmv	Outlet NOx, wppmv	Average Concentration, dppmv @ 3% O_2				
			Test Condition Code	Temp., °F	Flue Gas, kwscfm	NH_3/NOx			NH_3	SO_2	SO_3	HCl	N_2O
J	11Jul95	Outlet	39	750	0.40	1.0	317	100	3.3	—	—	—	—
	03Jun95	Inlet	22	700	0.40	0.8	—	—	—	1,744	6.1	—	—
	03Jun95	Outlet	22	700	0.40	0.8	—	—	—	1,663	0.3	—	—
	16Jun95	Inlet	22	700	0.40	0.8	—	—	—	—	—	—	2.0
	16Jun95	Outlet	22	700	0.40	0.8	—	—	—	—	—	—	1.6
	15Jun95	Outlet	2	620	0.24	0.8	210	99	0.9	—	—	—	—
	15Jun95	Outlet	6	620	0.40	0.6	229	133	1.0	—	—	—	—
	15Jun95	Outlet	7	620	0.40	0.8	233	106	1.3	—	—	—	—
	10Jul95	Outlet	9	620	0.40	1.0	255	107	2.2	—	—	—	—
	11Jul95	Outlet	14	620	0.60	1.0	233	57	5.1	—	—	—	—
	16Jun95	Outlet	21	700	0.40	0.6	222	114	<0.8	—	—	—	—
	16Jun95	Outlet	22	700	0.40	0.8	225	110	0.8	—	—	—	—
	13Jul95	Outlet	24	700	0.40	1.0	238	72	2.5	—	—	—	—
	16Jun95	Outlet	26	700	0.60	0.6	229	123	1.1	—	—	—	—
	17Jun95	Outlet	27	700	0.60	0.8	223	100	1.4	—	—	—	—
	11Jul95	Outlet	29	700	0.60	1.0	234	62	3.6	—	—	—	—
	17Jun95	Outlet	36	750	0.40	0.6	206	118	<0.8	—	—	—	—
	17Jun95	Outlet	37	750	0.40	0.8	211	107	0.9	—	—	—	—
	13Jul95	Outlet	39	750	0.40	1.0	231	74	2.5	—	—	—	—
	01Jul95	Inlet	22	700	0.40	0.8	—	—	—	1,568	6.6	—	—
	01Jul95	Outlet	22	700	0.40	0.8	—	—	—	1,490	11.2	—	—
	16Jun95	Inlet	22	700	0.40	0.8	—	—	—	—	—	—	2.0
	16Jun95	Outlet	22	700	0.40	0.8	—	—	—	—	—	—	2.9

[a] Dash indicates that no tests were performed at these conditions.

Table A-12. Monthly Average Coal Analyses

Month	Ash, wt%[a]	Sulfur, wt%	Carbon, wt%	Hydrogen, wt%	Nitrogen, wt%	Oxygen, wt%	Chlorine, ppmw
Mar 93	9.24	2.83	75.05	5.09	1.52	6.27	1514
Apr 93	8.87	3.01	74.86	5.04	1.57	6.65	1882
May 93	9.26	2.93	75.06	5.09	1.60	6.06	1345
Jun 93	9.74	2.91	74.87	5.10	1.52	5.86	293
Jul 93	10.09	3.02	74.23	4.98	1.55	6.13	1341
Aug 93	9.36	2.86	74.77	5.06	1.57	6.38	1429
Sep 93	10.55	2.94	73.95	4.96	1.57	6.03	1716
Oct 93	10.23	2.51	73.74	5.00	1.57	6.95	812
Nov 93	9.87	2.28	74.62	4.95	1.63	6.65	1210
Dec 93	9.01	2.62	75.51	5.04	1.66	6.16	1395
Jan 94	9.84	2.80	75.27	4.97	1.59	5.53	858
Feb 94	9.39	2.88	75.08	4.94	1.58	6.13	1116
Mar 94	9.69	2.78	75.31	4.99	1.59	5.64	1759
Apr 94	8.86	2.60	75.06	4.91	1.59	6.98	3403
May 94	8.92	2.78	75.10	4.96	1.57	6.67	2236
Jun 94	8.65	2.68	74.69	5.04	1.56	7.38	2092
Jul 94	8.63	2.64	74.97	5.02	1.59	7.15	2391
Aug 94	8.91	2.44	74.73	4.95	1.62	7.35	1957
Sep 94	9.08	2.63	74.36	4.99	1.58	7.36	1801
Oct 94	9.18	2.54	74.31	4.97	1.57	7.43	2630
Nov 94	8.96	2.42	74.92	5.00	1.61	7.09	2445
Dec 94	10.04	2.51	73.29	4.93	1.59	7.64	3039
Jan 95	9.46	2.24	74.26	4.99	1.60	7.45	3073
May 95	9.73	2.19	73.71	4.81	1.58	7.98	1477
Jun 95	8.40	1.89	76.12	5.07	1.56	6.96	2538
Jul 95	7.75	1.14	77.40	5.11	1.61	6.99	185

[a] All concentrations presented on dry basis.